A Critical Analysis of Standards-Based U.S. Middle School Textbook in Terms of Energy Concept

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Abstract: The U.S. science education went through reforms in 1990s and resulted in producing the National Science Education Standards (NSES). A middle school science curriculum, Investigating Earth Systems was newly developed based on the standards. The purpose of this study was to examine how congruent the standards-based science textbook is with the visions of the standards and what characteristics it has. Two instruments were used in analysis: Textbook Questioning Style Assessment Instrument (TQSAI) and Openness of Laboratory Activity and NSES’s Content Standards on Energy. This study focused on energy module in the textbook. Results indicated that Investigating Earth Systems included almost half the entire pages of energy module were consisted of questions in which experiential questions were dominantly used. In addition, both lower-order and higher-order questions were used in balance throughout the entire module of energy. The energy-related concept dealt in Investigating Earth Systems reflected well what was suggested in NSES. The implications were discussed in this paper.

Keywords: Standards-based curriculum, middle school science textbook, inquiry, question type

요약: 1990년, 미국의 과학교육은 개혁을 맞이하였고 국가표준이 개발되었다. 중학교 과학교과정
‘지구계 탐사하기(Investigating Earth Systems)’가 그 국가표준을 바탕으로 새롭게 개발되었다. 본 연구의 목적은 이러한 개혁과 개발된 교육과정이 얼마나 국가표준을 잘 반영하고 있는지, 어떤 특징이 있는지를 조사하였다. 국가표준 반영 정도에 대한 조사도구는 탐구의 근간이 되는 실험유형조사, 교과내용의 탐구유형 조사였으며, 특성에 대한 조사도구는 국가표준 과학내용이었다. 특별히 ‘에너지 단원’은 분석대상이었다. 분석 결과, 분석대상 교과서는 설명하는 문장 가운데, 거의 절반이 질문으로 구성되어 있고, 질문의 유형 또한 경험에 바탕을 두 질문이었다. 또한 낮은 사고력, 높은 사고력을 요구하는 질문들이 균형 있게 사용되었다. 또한 국가표준의 제한된 에너지 개념을 모두 잘 반영하였고, 탐구실험이 강조되었다. 이러한 결과의 의미를 본 논문 발의에 토의하였다.

주요어: 미국 국가표준 과학내용, 미국 중학교 과학교과서, 탐구, 실험유형

I. Introduction

In the U.S., a new middle school (5-8) science curriculum, Investigating Earth Systems...
(IES): An Inquiry Earth Science Program (Smith et al., 2002) was developed as a product of reform efforts in science education. This new textbook was special since it was based on the recommendations of National Science Education Standards [NSES] (NRC, 1996). This study was particularly interested in examining in what ways and how congruently the new curriculum was reflecting the visions of NSES. Therefore, a critical analysis is yet to be done in this regard. In the study of curriculum including development and analysis, a critical analysis is useful as it provides information, interprets, and examines the purpose, argument, main ideas of the curriculum along with its structures and outlines. In this study, a critical analysis is newly defined as follows:

An appraisal based on evidence and careful analytical evaluation about the purpose, argument, main ideas of a curriculum along with its structures and outlines.

The key point of a critical analysis is to inform the readers in a reasonable and concise manner to better understand the curriculum by mentioning its weakness and strengths. In addition, the analysis provides evidence from the text examined including, possibly, quotes and passages that signify the value, truth, validity, and goodness of something about the curriculum. In particular, a critical analysis in this paper provides topical information, evaluative interpretation, and summative conclusion. The topical information helps understand the philosophy, and rationale of the curriculum topics under analysis. The evaluative interpretation explains the meaning of the curricular elements examined, therefore requiring a correct understanding of it. The summative conclusion provides a summary of conclusive opinions about the work and contemporary valid justification for them.

1. Topical Information

This study examines how standards-based curriculum presents the concept of energy at the middle school level to meet the visions of national reforms in science education. This study particularly chose a textbook, Investigating Earth Systems (IES): An Inquiry Earth Science Program (Smith et al., 2002) for analysis since it is a product of reform efforts in in science education. IES is the U.S. middle school textbook developed based on the recommendations of National Science Education Standards (NRC, 1996). It is a new curriculum developed as an alternative to the traditional curriculum. The philosophy of this new curricular reform was relevancy, consistency, flexibility, and inquiry. That is, science should be taught in inquiry-based approach. However, a study of how this particular curriculum has presented the concept of energy in alignment with the visions recommended by the National Science Education Standards is yet to be studied. The U.S. middle school curriculum has recently gone through revisions and changes that were fundamentally based on several reform documents, including Science for All Americans (AAAS, 1989), Benchmarks for Science Literacy (AAAS, 1993), and most importantly National Science Education Standards (NRC, 1996) in which the
importance of a curriculum is described, reiterated, and infused in teaching and learning and in the development of educative materials (Davis & Krajcik, 2005). In contemporary perspectives of teaching science, the textbooks impacts how content is delivered in teaching (NRC, 1996, p. 22) so that all students could learn meaningfully (AAAS, 1989). Given the fact that textbooks can be a powerful tool for impacting teachers' teaching practice and subsequently improving student learning (Ball & Cohen, 1996), the textbook's content and structure become critical to the accountability of school science education. Park and Lavonen (2013) argued that a textbook is regarded as curriculum; yet, a science textbook is just a part of the curriculum that teachers utilize as guidebook to guide their teaching. Many teachers perceive a textbook as an important part of their instruction, including how their subject content knowledge is delivered and what is assessed. Thus, they use a textbook as a method and assessment of teachers' teaching, which often becomes inseparable from their everyday routine in the school curriculum. So a textbook becomes an essential part of teaching and assessment. When evaluating science curriculum materials, the administrators and teachers are to examine how curriculums are in alignment with the reform documents including national and/or local science standards (Kulm et al., 1999). One of the significant findings of evaluating a quality textbook is that teachers are over-dependent on textbooks for their teaching (Park, 2005), which is claimed to be an obstacle to a success of curricular reform and reform efforts in science education (Yager, 1980). We have seen, however, a couple of curricular reform efforts to lower down the over-dependence on textbook in science teaching by developing a new curriculum using new pedagogical perspectives and learning theories. The *Investigating Earth Systems: An Inquiry Earth Science Program* is one of the above efforts. IES is a new national curriculum funded in part by the National Science Foundation and the American Geological Institute Foundation. Its pedagogy and visions were based on the recommendations of National Science Education Standards (NRC, 1996).

The purpose of this study was (1) to analyze how the concept of energy were presented, and (2) to present evidence how congruent these two curricula are in terms of inquiry-based science with the visions of reform provided by the NSES. The *Investigating Earth Systems (IES): An Inquiry Earth Science Program* middle school science curriculum claimed that the NSES recommendations regarding content, teaching, assessment, and professional development were to have been evident throughout the IES materials. Regarding the above first purpose, this study used three topics as tool to examine the energy concept presentation: renewable-sources, transportation (electricity and power), and conservation and environment. Concerning the second purpose, this study particularly chose the questioning style and level of inquiry laboratory activities that represents key reform recommendations of the NSES (NRC, 1996) since the two indicators for determining the congruence between the recommended standards of the NSES and the *Investigating Earth Systems: An Inquiry Earth Science Program* materials.
2. Inquiry

In the U.S., curriculums have been newly developed as a product of the reforms in science education. For example, the National Science Education Standards [NSES] (NRC, 1996), as one of the major curriculum reform movements in science education, influenced the way science curriculums were developed for schools. The NSES’s visions were infused into the new middle school science curriculum, *Investigating Earth Systems (IES): An Inquiry Earth Science Program* (Smith et al., 2002). One of the major concepts of the reformative visions in science education is *inquiry* of NSES. Inquiry provides a framework for ideas to be organized into a textbook. The activities presented in the textbook was developed to meet the recommendations of National Science Education Standards as they influenced its philosophy, teaching, learning, professional development, assessment, and content (Park et al., 2005). A change of the curriculum is followed by new content, new structure of content, new pedagogical philosophy including learning theories and assessment. As a few studies suggested key knowledge to be addressed in newly developed textbooks by emphasizing the inclusion of curriculum goals and content that reflects the contemporary learning theories (Chiappetta et al., 1991; Staver and Bay, 1987), inquiry as a key contemporary learning strategy was infused in textbooks including *IES*. Inquiry is one of the key recommendations of National Science Education Standards. Inquiry-oriented approach with a constructivist learning theory influenced the way that science content was structured and taught. *Investigating Earth Systems* is an activity-driven curriculum using inquiry approach as presented in NSES (NRC, 1996, p. 23), "inquiry is a multifaceted activity that involves making observations, posing questions, planning investigations, using tools to gather, analyze, and interpret data, and proposing answers, explanations, and communicating the results." This definition provided a framework for students to find solutions to real-world problems through a process of investigations including formulating questions (Bereiter et al., 1989), planning investigations (Schauble et al, 1995), using tools to gather and analyze data (Vellom et al., 1999), interpreting and proposing answers and explanations (Chinn et al., 1993), and finally communicating the findings. These procedures become important in conducting in any of scientific research. As the reform recommendations apparently influence how the curriculum content is structured, the study of textbook analysis should be rooted in the contemporary learning theories and inquiry concept recommended by the NSES.

3. Questions

Scientific inquiry often starts out with a question. Questions used in scientific investigations are "a set of good questions that are relevant, answerable, and scientifically meaningful (Marbach-Ad et al., 2000). The type and the level of questioning can determine how effective discussions are (Rowe, 1986). If questioning only targets the knowledge, recall, and comprehension level of bloom’s taxonomy, then the science would be a limited relevance to students. Questions should stimulate students to think as if they were scientists to reduce the notion
that science should only be reserved for a particular group. If questions ask for simple knowledge and facts, then students remain not critically thinking and assessing. However, questions that ask for analysis, synthesis, and evaluation in bloom’s taxonomy would require critical thinking and assessment (Beatty et al., 2006). Thus, the level of questioning becomes critical during the instructional process of inquiry activities and learning goals. Regarding this particular issue, Lowery and Leonard (1978) developed an instrument to analyze the type of questions in textbooks. They argued that the questioning style can be a good predictor of textbook quality that may help teachers expand their horizon of selection criteria when examining a textbook for their schools or school district. Question type and level of inquiry activities can be one legitimate evaluation tool to examine how congruent a textbook is in terms of what National Science Education Standards presented about inquiry, since inquiry and question type are closely integrated, to move forward when solving a problem in scientific investigations” (Park & Lavonen, 2013).

II. Methodology

1. Sample

The textbook used for analysis in this study was Investigating Earth Systems (IES): An Inquiry Earth Science Program (Smith et al., 2002). Only the concept of energy was excerpted from the textbook and analyzed in terms of the way the energy topics were presented, the questioning style and level of inquiry laboratory activities. Unlike the traditional textbooks, IES was developed with the pedagogy that reflected the recommendations of the National Science Education Standards. IES was comprised of ten modules including Climate and Weather, Energy Resources, Fossils, Our Dynamic Planet, Materials and Minerals, Oceans, Rocks and Land Forms, Soil, Water as a Resource, Earth in Space: Astronomy. Each module has from 6 up to 8 investigation activities that are hands-on and inquiry-based. Among the ten modules, the Energy Resources module provided seven investigation activities including Tracing Electricity to Its Source, Uses of Energy Resources, How Fossil Fuels are Formed, Sources and Uses of Petroleum, Exploring for Petroleum, Solar Energy, and Using Energy Resources Wisely. In each investigation activity, students will use hands-on, inquiry-based explorations to investigate (Smith et al., 2002):

- where energy resources come from;
- how energy resources are converted into electricity;
- how fossil fuels form and are found;
- the importance of renewable energy resources; and
- the importance of energy conservation.

The module of Energy Resources described what was supposed to be done with regard to student activities. In the module, students interpret energy data to understand the historical trends and current use of energy resources. As they perform a series of inquiries, students
explore the concept of energy transformation from fossil fuel, and investigate how to generate electricity. Students also use modeling activities to understand the processes by which natural energy resources are discovered and extracted. Students then investigate renewable energy resources and assess the significance of all energy sources for contemporary and future human use (Smith et al., 2002).

2. Level of Inquiry Activities

A level of openness was used to analyze the inquiry activities included in *Investigating Earth Systems*. "The instruction of inquiry activities uses a certain level of openness according to a classification scheme designed by Schwab (1962) and further elaborated by Herron (1971). There are four different levels of laboratory activities to be used as criteria: levels 0-3. Each level is determined by the openness of question, procedures, and solution. For instance, in a level 0 laboratory activity, all three learning processes including questions, procedures, and solutions are given. Table 1 shows Herron’s level of openness of laboratory activities" (Park & Lavonen, 2013).

<table>
<thead>
<tr>
<th>Level</th>
<th>Problems</th>
<th>Procedures</th>
<th>Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Given</td>
<td>Given</td>
<td>Given</td>
</tr>
<tr>
<td>1</td>
<td>Given</td>
<td>Open</td>
<td>Open</td>
</tr>
<tr>
<td>2</td>
<td>Given</td>
<td>Open</td>
<td>Open</td>
</tr>
<tr>
<td>3</td>
<td>Open</td>
<td>Open</td>
<td>Open</td>
</tr>
</tbody>
</table>

Heron’s framework is well suitable for discussing the level of inquiry activities. Even activities were rated by two raters who determined the level of openness based on the descriptions of classification. Two raters independently assessed the level of laboratory activities for each activity. The agreement of the raters was served to provide the inter-rater reliability with face validity.

3. A Flow of Investigation Activity

The flow of each activity goes through the inquiry-based learning cycle that consisted of seven steps; key question, investigate, inquiry process highlights, student journal, digging deeper, review and reflect, and putting it all together (It’s About Time, 2010). The following flow was excerpted from a Teacher Guide on the website of It’s About Time [Key Question: Before you begin, you will be asked to think about the key question you will investigate. You do not need to come up with a correct answer. Instead you will be expected to take some time to think about what you already know. You can then share your ideas with your small group...
Investigate

Geoscientists learn about the Earth system by doing investigations. That is exactly what you will be doing. Sometimes you will be given the procedures to follow. Other times you will need to decide what question you want to investigate and what procedure to follow.

Inquiry

You will use inquiry processes to investigate and solve problems in an orderly way. Look for these reminders about the processes you are using. Throughout your investigations you will keep your own journal. Your journal is like one that scientists keep when they investigate a scientific question. You can enter anything you think is important during the investigation. There will also be questions after many of the Investigate steps for you to answer and enter in your journal. You will also need to think about how the Earth works as a set of systems. You can write the connections you make after each investigation on your Earth System Connection sheet in your journal.

Digging Deeper

Scientists build on knowledge that others have discovered through investigation. In this section you can read about the insights scientists have about the question you are investigating. The questions in As You Read will help you focus on the information you are looking for.

Review and Reflect

After you have completed each investigation, you will be asked to reflect on what you have learned and how it relates to the "Big Picture" of the Earth system. You will also be asked to think about what scientific inquiry processes you used.

Putting It All Together

In the last investigation of the module you will have a chance to "put it all together." You will be asked to apply all that you have learned in the previous investigations to solve a practical problem. This module is just the beginning! You continue to learn about the Earth system every time you ask questions and make observations about the world around you.

As seen in the above flow of each activity, the essential features of inquiry were infused in the curriculum, which is one of the key ideas of the NSES’s visions.

4. Questioning Style

Textbook Questioning Strategies Assessment Instrument (TQSAI) was used in the analysis
of *Investigating Earth Systems (IES): An Inquiry Earth Science Program* (Smith et al., 2002). TQSAI was developed by Lowery and Leonard (1978). Using TQSAI, the unit of energy in *IES* was examined in terms of styles of the questions and processes (see Appendix A). Before analysis began, two science educators—a college professor and a school science teacher—met face-to-face as a rater and discussed, clarified, and cleared confusions about each item of TQSAI until they felt confident about using it (mostly they agreed 90-100%). Two raters used a couple of samples that came from the textbook and examined one by one to see if it matched the definition of TQSAI items. Two trained raters evaluated each question by using two-dimensional grids upon which items could be tallied from pages of energy concept in IES textbook. Two raters independently examined the categorization of all questions included in the pages of energy concept and then checked for agreement. The agreement reached for the question categories was .81 (correlation coefficient r), which is considered high (Ericsson & Simon, 1993). The examination results provide useful information for teachers, parents, and school district administrators when selecting quality textbooks for science teaching and learning.

### III. Results

The topics of energy included in the *Investigating Earth Systems* textbook were found as follows:

- Investigation 1: Tracing Electricity to Its Source
- Investigation 2: Uses of Energy Resources
- Investigation 3: How Fossil Fuels are Formed
- Investigation 4: Sources and Uses of Petroleum
- Investigation 5: Exploring for Petroleum
- Investigation 6: Solar Energy
- Investigation 7: Using Energy Resources Wisely

In National Science Education Standards, energy related concepts, included in physical science standards, suggest four topics: **Resources of energy, Transfer of energy (electricity and power), Conservation of energy and Interactions of energy and matter** *(NRC, 1996. p. 106).* "Interactions of energy and matter" is the same topic as transfer of energy. For example, water, sound, light, and seismic waves have energy and can transfer energy when they interact with matter. When the above four topics serve as criteria for analysis in this study, the concepts dealt in IES demonstrated Table 2.

As shown in Table 2, all the topics recommended by NSES were evident in the middle school textbook of *Investigating Earth Systems*. Some topics were dealt more than once throughout the investigations of energy module.

The general features of the textbook *Investigating Earth Systems (IES)* demonstrate the features in structure and organization. Table 3 shows the results of the examination. The per-


Table 2. Comparison of energy concepts between IES and NSES

<table>
<thead>
<tr>
<th>Investigating Earth Systems: Energy Resources (76 pages)</th>
<th>Recommended energy concepts by NSES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investigation 1: Tracing Electricity to Its Source</td>
<td>Resources of energy &amp; Transfer of energy</td>
</tr>
<tr>
<td>Investigation 2: Uses of Energy Resources</td>
<td>Resources of energy &amp; Transfer of energy</td>
</tr>
<tr>
<td>Investigation 3: How Fossil Fuels are Formed</td>
<td>Resources of energy</td>
</tr>
<tr>
<td>Investigation 4: Sources and Uses of Petroleum</td>
<td>Resources of energy &amp; Transfer of energy</td>
</tr>
<tr>
<td>Investigation 5: Exploring for Petroleum</td>
<td>Resources of energy</td>
</tr>
<tr>
<td>Investigation 6: Solar Energy</td>
<td>Resources of energy &amp; Conservation of energy</td>
</tr>
<tr>
<td>Investigation 7: Using Energy Resources Wisely</td>
<td>Conservation of energy &amp; Interaction of energy and matter</td>
</tr>
</tbody>
</table>

As all ten modules together are consisted of 74 laboratory activities, IES follows an inquiry-oriented curriculum with less information that is line with what AAAS recommended "less is more." Energy unit is consisted of 76 pages, which is 10.6% of the entire page of 717 pages of the textbook. With this portion allocated to learning about energy concept, IES provides deeper understanding of the concept through hands-on laboratory activities about the Earth systems.

1. Questioning Style

Using the Textbook Questioning Strategies Assessment Instrument (TQSAI), this study examined the type of question included in the entire of 76 pages about energy. Data was analyzed to determine the degree to which each item met the vision outlined in the NSES.
Lowery and Leonard (1978) provided the definition of each questioning style in TQSAI (see Appendix A). Fifty seven pages were all selected for analysis, and the results are presented in Tables 3 and Fig. 1 & 2.

2. Experiential and Non-Experiential Questions

Table 3 showed the results of examining the number of questions and the percentage of questions to sentences. *Investigating Earth Systems* included uniquely many questions per sentence (42.4%). In other words, it has quite a number of questions that are needed for inquiry activities. In addition, *Investigating Earth Systems* has more experiential questions (13.3%). Experiential questions are questions that ask what student experienced in the laboratory activities. For instance, an example of experiential question is "What evidence do you have from this investigation that the Sun’s heat and light can be used as a form of energy?", "What have you learned about energy use from past to present in the United States?" Also, an example of non-experiential question is "Why are energy resources important?", "What is energy?" The percentages of experiential questions are presented in Table 4.

**Table 4.** Percentages of questions and experiential questions per sentence included in energy topic

<table>
<thead>
<tr>
<th>Textbooks with sample pages</th>
<th>Number of questions</th>
<th>Number of experiential questions</th>
<th>Number of sentences</th>
<th>Percentage of questions per sentence</th>
<th>Percentage of experiential questions per sentence</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Investigating Earth Systems</em></td>
<td>201</td>
<td>63</td>
<td>474</td>
<td>42.4%</td>
<td>13.3%</td>
</tr>
</tbody>
</table>

On the other hand, the percentages of non-experiential questions for the total numbers of questions included in the pages of energy topic are shown in Fig. 1. In *Investigating Earth Systems*, direct-information question type was predominant (45.8%), followed by open-ended question type (21.4%). Focusing and valuing question types were found one question (0.5%) each in the pages of energy topic.

Experiential questions were classified into a hierarchy of the science/learning processes, including lower-order (observing, communicating, comparing, and organizing) and higher-order (experimenting, inferring, and applying) processes (Ebel and Frisbie, 1991). This study analyzed the experiential questions by using Ebel and Frisbie’s scheme. The results were summarized in Fig. 2. Percentages were calculated for the number of questions in each cell compared to the total number of questions included in the *Investigating Earth Systems* textbook. As shown in Fig. 2, there were two dominating types of questions used: Observing (30%) and Inferring (31%). Comparing and Experimenting types of questions are used quite a lot but not as much. Communicating and Organizing and Applying question types were minimally
Results showed that U.S. middle school curriculum *Investigating Earth Systems* has 717 pages in total that are consisted of 10 modules to investigate about the earth systems. Each of the ten modules has laboratory experiments that required students to explore using a great portion of questions (42.4%) vs. sentences. In experiential questions, the textbook dominantly used the types of observing and inferring questions. On the other hand, direct information and open-ended questions were dominantly used in terms of non-experiential question type. Results also demonstrated that, according to the science and learning process scheme (Ebel et al., 1991), the observing, comparing, experimenting, and inferring question types were commonly used.
in one of the U.S. middle school science textbooks that were developed as a result of reform.

3. Level of Laboratory Activities

Energy module provided seven investigations as a laboratory activity in *Investigating Earth Systems*. Throughout the curriculum under analysis, seven investigative activities all fall into level 1 which problems and procedures were given and only solution open. This result came through two raters who determined the level of openness based on the descriptions of investigations in energy module (57 pages).

### Discussions

A critical analysis provides an *evaluative interpretation of* textbook analysis in terms of the recommendations of reform. The purpose of this study was to evaluate the congruence between a curriculum and visions of reform, i.e., the National Science Education Standards (NSES). The alignment requires coherence of science content and themes in the textbook to promote student leaning (Park et al., 2013). This particular study examined how the NSES reform standards impacted the way middle school science contents were structured and analyzed how the type of questions were asked in textbook. Coherence of curriculums becomes critical when developing a curriculum that designed to bolster students’ effective learning (NRC, 2007) as science is carried out by logics and reasonable explanations that often required coherence. One of the reform documents emphasized coherence was National Science Education Standards (NRS, 1996) that recommended to explicitly promoting more emphasis on inquiry-based science instruction to develop students’ deep understanding of science concepts. The new framework of science education expands and advances inquiry-based science teaching by incorporating engineering and mathematics components into science instruction (NRC, 2011) within the full inquiry framework (NRC, 1996, p. 23). NSES required a significant shift as to what and how science is taught to K-12 classrooms. However, inquiry-based science instruction still remained as a challenge in especially middle school science because middle school students’ ability of inquiry performance. So the way the content is presented in curriculum, as it demands in instruction, becomes critical in students’ learning.

1. Energy Concept Presentation

As results indicated in Table 2, NSES’s recommended topics were all evident in the middle school textbook *Investigating Earth Systems*. Some topics were included in the textbook multiple times throughout the different investigation activities of energy module. IES congruently presented content of energy topics with what was recommended in NSES. Energy concepts that students learn are current and in balance that covers what is supposed to be addressed in energy area. *Investigating Earth Systems* contained 10 modules and 74 activities. In its entirety, *Investigating Earth Systems* presented more laboratory activities and fewer topics (see
Table 3) that it used to be. This textbook trend is in line with one of the emphases of science curriculum reforms ‘less is more’, as envisioned in *Science for All Americans* (AAAS, 1989). Energy module is one of the 10 modules and it has 7 activities (9.5%). The module consisted of topics, and the topics consisted of concepts. So the more modules included in a textbook, the more concepts may be taught. Fewer modules may mean that the teaching focus is not on the quantity but on the depth and understanding. This message reinstated reform emphases since the national reform standards emphasized what all students should know and be able to do by the certain grade levels, which gives a key idea when designing a curriculum (Park, 2005). Project 2061 recommended that teachers should "introduce ideas gradually, in a variety of contexts, reinforcing and extending them as students mature by concentrating on fewer topics" (AAAS, 1989, p. xviii). Therefore, the instructional message of ‘less is more’ is to allow students to develop deep understanding of scientific concepts through inquiry-based investigations than the ‘more concepts to teach’ environment in which students are demanded to memorize decontextualized knowledge and facts (Park et al, 2013). It seems that *Investigating Earth Systems* emphasized the importance of inquiry-based activities in middle school science. At the same time, *Investigating Earth Systems* focuses on teaching fewer concepts in order to teach deeper level of concept. Inquiry often begins with a question. Energy module uniquely utilized many questions (42.4%), which are almost half the entire sentences.

2. Openness of Laboratory Activities

All of the seven experimental activities included in *Investigating Earth Systems* were found to be the level 1 in which problems and procedures are given with solutions left open. None of the activities provided levels 2 and 3. This result is not surprising as we have seen in other studies regarding the openness of a laboratory activity (Park, 2005; Chiang-Soong, 1988). Park (2005) examined the openness level of activities included in three earth science textbooks in which one was a reform-oriented curriculum and two were traditional ones. His study concluded with the same result that level 1 dominated in all of the lab activities. Chiang-Soong’s study also concluded that almost all of the laboratory activities were at levels 0 and 1. As results indicated in this study, *Investigating Earth Systems* provided no high-level openness of activities that provide inquiry science and problem-solving skills. Although reform efforts stressed inquiry as a key component of science instruction, the reality of curriculums being used in schools sound remote from achieving the goal of the reform. However, as Ball and Cohen (1996) argued that curriculum can be a powerful tool for impacting teachers’ instruction and subsequently improving student learning, it is recommended that curriculum be developed to meet what research says about inquiry instruction in the laboratory experiments to improve students’ science learning. Even if *Investigating Earth Systems* provided level 1 activity, students were continuously provided opportunities to practice inquiry problem-solving skills throughout the course of experiments including gathering, analyzing, interpreting data and proposing solutions, explanations, and predictions, and communicating the results (NRC,
1996, p. 23). This aspect is congruent with the recommendations of NSES. These skills are acquired only when students engage in "active inquiries" as frequently as possible (NRC, 1996, p. 145). Specifically, the NSRS visions regarding laboratory activities recommended that students actively participate in scientific investigations, and actually use the cognitive and manipulative skills during the course of scientific explorations. However, problem-solving skills are not easy to acquire but to require a number of opportunities to practice in real contexts of science. Therefore, it is recommended that students be offered many opportunities to practice problem-solving skills in different contexts of science in middle school science.

3. Questioning Type

Results about the questioning types demonstrated that energy module in Investigating Earth Systems used a number of questions (42.4%). As emphasized in NSES, Investigating Earth Systems utilized many questions as students were guided to find as a solution in inquiry-based investigations. Among the questions used in energy module, the number of experiential questions was 63 (31.3%=63/201×100). This result is higher than what was found in literature. For example, in Chiang-Soong’s study (1988), BSCS biology used 5.9% experiential questions and Physical Science Study Curriculum (PSSC) used 12.0% experiential questions. Research says that more experiential questions are effective than non-experiential questions. For instance, Piagetian research continuously lend supports to the fact that direct experiences played a vital role to effectively impact students’ learning than indirect and passive experiences (Piaget, 1964; Lawson and Renner, 1975; Stavy, 1990). This idea implies that textbooks should use more experiential questions than non-experiential questions when presenting subject content knowledge. Concerning non-experiential questions, Investigating Earth Systems used the types of direct information questions and open-ended questions dominantly. Regarding the percentage of questions used for science and learning processes (Ebel et al., 1991), little was used in questions including communicating, organizing, and applying questions. Unlike Chiang-Soong’s study (1998), results showed that Investigating Earth Systems used both lower-order questions (observing, communicating, comparing, and organizing) and higher-order questions (experimenting, inferring, and applying) in balance in terms of the hierarchy of science/learning processes (Ebel et al., 1991). As recommended in NSES, questioning in scientific inquiry promotes students’ investigation since they are asked to utilize higher-order thinking skills. Students’ active involvement in formulating inquiry questions helps developed students’ thinking ability by deepening scope and depth of scientific concepts (NRC, 1996). Krol et al. (2004) argued that students’ collaborative learning experiences with their peers improve their thinking process. Inquiry activities support the ideas of collaborative experiences in group, thinking process, higher-order thinking, and higher-level cognitive responses (Martin, 1979). When engaging students in forming inquiry questions, NSES emphasized the authenticity of questioning. For instance, NSES stated, "inquiry into authentic questions from student experiences is the central strategy for teaching science" (NRC, 1996, p. 31).
V. Conclusion

U.S. middle school science textbook *Investigating Earth Systems* was born as a result of reform in science education. A critical analysis of the curriculum provides a summative conclusion based on the results of topical information and evaluative interpretation. Energy concepts were presented in line with what was recommended in the National Science Education Standards, which include Resources of energy, Transfer of energy (electricity and power), Conservation of energy and interactions of energy and matter (NRC, 1996, p. 106). In addition, *Investigating Earth Systems* is well matched with of the key ideas "less is more" of reform movement in science education. For instance, *Investigating Earth Systems* has less number of concepts and more number of laboratory activities. In performing inquiry, questioning types and skills included in energy module of *Investigating Earth Systems* are congruent with what was suggested in NSES. For instance, more questions were asked by using experiential questions and also lower-order and higher-order questioning in balance. As inquiry requires effective skills, students should be constantly offered opportunities to practice their skills of collecting data interpreting and posing explanations. The opportunity of performing inquiry science requires rigid data quality assurances especially when school science is often viewed as confirmatory science. To achieve data quality, effective training is needed to develop students’ higher-order thinking skills.

References

Rowe, M., 1986, Waiting time: Slowing down may be a way of speeding up, Journal of Teacher


Appendix A. Textbook Questioning Style Assessment Instrument (TQSAI)

Not Experiential

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Experiential

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Definitions of Types of Questions

On the TQSAI, the question categories are sequenced along a horizontal dimension. The categories are defined as follows:

Rhetorical Questions: Questions that do not expect some participation by the reader. Such questions never require the student to do anything, thus non-experiential and are tallied in a special cell on the TQSAI.

Direct-information Questions: Questions that ask the reader to recall or recognize specific information (concepts, principles, laws and so on) read, heard or previously discussed.

Focusing questions: Questions that contain clues that suggest what the expected response is to be. Such questions guide the student toward an answer that the author wants to be developed in the student’s own terms.

Open-ended questions: Questions that do not indicate one expected answer. Such questions invite exploration of relationships and consideration of meaning or implications.

Valuing Questions: Questions that ask the reader to make a cognitive or an affective judgment or to explain the criteria used in an evaluation.

The science/learning processes are sequenced along a vertical dimension on the TQASI. They are defined as follows:
Observing: Questions that ask the reader to look, listen, touch, taste, smell, and the like. Such questions may ask the reader how s/he felt or what thoughts were elicited.

Communicating: Questions that ask the reader to verbalize, write, picture, and the like. Such questions may ask the reader to furnish a name, offer a descriptive term, or verbalize a rule. They may ask the reader what was hopeful or to identify the words that elicited a feeling.

Comparing: Questions that ask the reader to compare lengths, weights, capacities, or times. Such questions may ask the reader to identify similarities, to measure, to countparts, or to state a preference and the reason for the preference.

Organizing: Questions that ask the reader to seriate, order, sequence, group, or classify. The reader may be asked to sort into groups, to identify the basis for a grouping, or to provide criteria for a grouping.

Experimenting: Questions that ask the reader to hypothesize or to control and manipulate variables. The reader may be asked to identify conditions necessary for results, or whether and when to change hi/her attitudes on the basis of new evidence.

Inferring: Questions that ask the reader to synthesize, abstract, analyze, recognize patterns, predict, generalize, or to formulate a theoretical model. The reader may be asked to furnish a reason for an occurrence, provide a conclusion, or to identify the generalizations that apply.

Applying: Questions that ask the reader to use his/her knowledge or to invent. The reader may be asked to embark upon a course of action based upon a choice of alternatives.