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Curriculum Reform Movement of Science Education in the US: A Case of Earth Science Curriculum

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Abstract: The United States curriculum reform movement has recently started in each area of science education. The initiatives on curriculum reform stem from a notion that the low rate of science curricula offered in schools has been a serious problem. The schools in the United States are not only facing a lack of offerings within science curricula but also low enrollment in science courses, especially in physics, chemistry, and earth science. This trend resulted in low performances on international achievement tests including TIMSS and PISA. This paper introduces the efforts to solve existing problems through curriculum reform; including ChemCom, BioCom, EarthComm, and Active Physics. In this paper, a discussion is presented to show how the curricula can help address the status quo in science education. More specifically, this paper focuses on curriculum reform in high school earth science (EarthComm), providing a closer look at the scope and sequence of the reform movement. EarthComm was chosen because it was released based on the development of the National Science Education Standards (NRC, 1996). Consequently, EarthComm became a curriculum that espoused the visions of the Standards, which has been guiding the reform of the US curriculum. At the end of this paper, two research outcomes of the EarthComm curriculum implementation in schools are discussed in terms of student learning and differences from conventional curricula.

Keywords: national science education standards, earth systems education, EarthComm, curriculum reform

Introduction

Science education in the US is in the midst of a new curriculum reform movement. One of the most recently published curriculum reforms is the Earth System Science in the Community (EarthComm) project supported by the National Science Foundation. This is the American Geological Institute project that was initiated in 1995 and continued through the year 2000. Some studies questioned the impact of most national curriculum projects because of the nature of assessment and evaluation information used as evidence for the successes (Yager, 1976; Townsend, 1976; Welch, 1968, 1969). However, other research reports claimed positive results (Clough, 1994; Shymansky, 1984; Kyle, 1984; Hurd, 1976; Myer, 1974; Ridgway and Pimentel, 1970; Merrill and Ridgway, 1969). One of the common aspects of all the multimillion-dollar projects in the US throughout the past three decades has been the assertion that education was in crisis thereby necessitating the new programs to resolve the crisis. The US education responded to this crisis by initiating various education reforms and initiatives, e.g., Nation at Risk and more recently No Child Left Behind Act. One of the key efforts was to develop a new curriculum to overcome the problem. More specifically US science education faced public concern, in part, because the international study of science and mathematics including TIMSS (Martin et al., 2000) showed that US students' science achievement scores were poor and below their peers' of counterpart countries such as Japan and Germany. US school curricula were criticized as one of the culprits for this poor result because US science textbooks tend to be "a mile wide and an inch deep" (Schmidt et al., 1996). It brought attention to the needs of new curriculum development for grade schools. In that vein, US science education is currently in the midst of reform in developing new curricula for students in K-12.

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In the past, the science curricula development in the US resulted in changes in K-12 classrooms. The launch of the Soviet Union's satellite *Sputnik I* in 1957 accelerated curriculum revision by generating public concern and support. With funding from NSF and various private foundations such as the Carnegie and Ford Foundations, many projects were undertaken to improve school courses in response to the increasing criticisms leveled against the US educational system. Major projects include Physical Science Study Committee (PSSC), Biological Sciences Curriculum Study (BSCS), Chemical Education Material Study (CHEM Study), Earth Science Curriculum Project (ESCP), Time, Space, and Matter (TSM), Elementary Science Study (ESS), Science Curriculum Improvement Study (SCIS), and Science-A Process Approach (SAPA). These new curricula focused on the nature, logical structure, and the processes of scientific inquiry while the traditional science curricula emphasized scientific facts, laws, theories, and technological applications (DeBoer, 1991; Klopfer, 1971). Several new types of curricula have been developed, which focus upon the relation of society to the lives of students. For example, Chemistry in the Community (ChemCom) was developed by the American Chemical Society in 1988, Biology in the Community (BioCom) by Leonard and Penick in collaboration with the National Association of Biology Teachers in 1996, and Active Physics by Eisenkraft in collaboration with the American Association for Physics Teachers in 1995. The main focus of these newly developed programs is on the relevancy of chemistry, biology, and physics to the lives of students in their own local communities. These changes are characteristic of many current reform efforts in science education including National Science Education Standards (NRC, 1996).

One of the common goals among these massive projects is to increase scientific literacy among all levels of students. The EarthComm curriculum (AGI, 2000a) is no exception. One of the EarthComm goals is to produce a citizenry which is more "Earth-knowledgeable and earth science literacy" In respond to current challenges and issues that the Earth faces, the school curriculum of earth science is called to change to meet the needs of students in understanding the nature of those challenges. The purpose of this paper is to review the recent efforts to reform science curricula in the US with some research outcomes from the implementation of a new earth science curriculum so as to see where the school earth science education is situated at and what and how we should teach to enhance our future generation's understanding about the Earth.

Why is the Textbook Central in Curriculum Reform?

The science textbook has long been a key issue in science instruction since many reports that the textbook plays a dominant role in science teaching and heavily influences what as well as how it is taught. Traditionally, many science teachers report that they rely almost entirely on textbooks for their teaching. A number of researchers have pointed out the centrality of the textbooks in typical teaching (Stake and Easley, 1978; Harms and Yager, 1981; Yager, 1983, 1992; Shymansky and Kyle, 1992; Weiss, 1978; Helgeson et al., 1977). For instance, Stake and Easley reported that "over 90% of the science teachers in a sample of 12,000 teachers said their instructional materials were the heart of their teaching curriculum 90-95% of the time" (Stake and Easley, 1978). They summarized the situation by stating, "Textbooks commanded teacher's and student's attention. In a way, they virtually dictated the curriculum. The curriculum did not venture beyond the boundaries set by the instructional materials." This overwhelming reliance on textbooks in science teaching and learning misled students as they became the only source of knowledge authority (Stake and Easley, 1978). Yager (1980) defined this almost complete dependence of science teaching on a single textbook as the essence of the current crisis in science education.

Many attempts have been made to diminish teachers' dependence on textbooks (Hurd, 1994; Kahl and Harms, 1981). One of the approaches is to develop a new curriculum that reflects and facilitates use of student experiences in their own communities and focusing on topics that affect the lives of students. Yager (1983) argued that textbooks lock teachers in a belief that the instructional process of lecture, question and answer, is guaranteed to produce knowledgeable students. He concluded his research with the statement, "The status of science education can be summarized in a single word: textbooks" (Yager, 1983). Stinner (1995) pointed out three shortcomings from the current trends about science textbooks. First, the typical belief about textbooks implicitly promotes the empiricist-inductivist picture of science (Stinner, 1989; Yager, 1983). The empiricist-inductivist believes that law and discoveries are guaranteed results of scientific observation. A second shortcoming is the belief that the instructional action in class is guaranteed to produce certain knowledge for students. Third, most textbooks are content-driven. Many research studies point to the general failure of textbook-centered science teaching and learning. Renner et al. (1990) reported that 61% of students showed no understanding and frequently misunderstanding after being taught concepts only with a textbook. Wandersee (1988) found that because college-level teaching is textbook-centered, only 6% of college students made a link to prior knowledge to the new concepts when they read a textbook. What then must be done to correct this failure?

The teacher becomes the focus of reform along with changes in the curriculum. Teacher behaviors are influenced by the curriculum, including textbooks (NRC, 1988). Therefore, it is pivotal for teachers to be aware of the quality of textbooks. They should have the ability to analyze and evaluate the curriculum and textbooks. The research findings suggest a sequence of criteria for textbook analysis (Chiappetta et al., 1991; Exline, 1989; Staver and Bay, 1987; Doran and Sheard, 1974). Specifically, Doran and Sheard (1974) suggested that textbook analyses should be based upon "the course objectives, the instructional setting, and student needs, interests, and capabilities." These studies emphasized not only the curriculum goals and content reflecting the contemporary scientific conceptions and learning theories but also the role of teachers in selecting textbooks. Similarly, Renner (1972) pointed to the need to recommend two kinds of key knowledge to be addressed and incorporated into the textbook of the future: the findings of modern learning theories about the nature of the learning process, especially the importance of paying attention to students; preconceptions, to identify them, respect them, and then to build on them.

The contemporary picture of the nature of science is that scientific conceptions, principles, theories, and laws are not enshrined but are evolving. They do not follow simply from observation in an inductivist manner, the diverse connections between scientific conceptions and discoveries, and between technology and society. From Renner's (1972) point of view, it is expected that textbooks must contain the currently accepted learning theories in science education and scientific conceptions about nature.

COM Curricula in Science Education

Sciences in the Community (COM) emerged as new science curriculum reform models were targeted for the high school level. The philosophy of COM curricula was fundamentally traced to match the proposed new goals in science education from Project Synthesis; these include dealing with Personal Needs, Societal Issues, Academic Preparation, and Career Education/Awareness (Kahl and Harms, 1981). The message of Project Synthesis was that school science should respond to students' personal needs and deal with current societal issues while focusing on student understanding of science in the context of technology and society. It was argued that school science should emphasize fostering positive attitudes towards science and being relevant to students' lives as well as improving understanding of the relationship among science, technology, and society. The COM curricula began with ChemCom developed by the American Chemical Society with funding, in part, from the National Science Foundation. The COM curricula include: Chemistry in the Community (ChemCom), Biology in the Community (BioCom), Active Physics, and Earth System Science in the Community (EarthComm).

Chemistry in the Community (ChemCom), developed by the American Chemical Society (1988), was the first product reflecting the aforementioned philosophy regarding the science curriculum. ChemCom, aimed at both college-bound and non-science major groups, was designed to motivate students to learn more chemistry through both science and the issues that face the daily lives of individuals and in their own communities (Sutman and Bruce, 1992). ChemCom was designed and developed as an effort to depart from tradition. This effort was evident in its objectives and content organization. One of the objectives was for "ChemCom to give students opportunity to understand how to deal with societal issues using chemical knowledge (Sutman and Bruce, 1992)." Hands-on investigations and laboratory activities were embedded in the curriculum and prevailed throughout the content of ChemCom. ChemCom is now in its fourth edition, still offering chemistry on a "need to know" basis through eight thematic units. Publication of ChemCom curriculum artifacts has influenced not only the development of EarthComm but also two other curricula: Active Physics and Biology in the Community (BioCom).

Active Physics, developed by the American Association of Physics Teachers and the American Institute of Physics with the assistance of the American Physical Society, is an NSF-supported curriculum development project for 9th-12th grade students. Active Physics was developed to improve students' attitudes and understanding of physics concepts. Five units of physics are all relevant to students' daily life, i.e., sports, transportation, health, the home, and making predictions. The purpose of the project was to develop an alternative physics course for high school students who do not ordinarily enroll in physics. Because of its limited prerequisite for mathematics and reading skills, this activity-based course can be successfully used with all students.

BioCom (Leonard and Penick, 1991), which was developed by a team of scientists, science educators, and high school teachers, is an NSF-funded curriculum for 9th or 10th grade high school general biology classes. It was designed to be relevant to student lives and user friendly for teachers. With inquiry-oriented instructional strategies incorporated, BioCom was developed to improve student attitudes while focusing on eight theme-based units. These units included 170 key concepts in biology and the nature of science and focused on hands-on activities and science readings (Clough, 1994).

Another new, NSF-funded, Active Chemistry curriculum was recently developed by with educators, scientists, engineers, and institutions, including members of the American Institute of Chemical Engineers (AIChE) for full-year high school general chemistry classes (It's About Time, 2002). It is another version of new high school chemistry curriculum espoused the visions of National Science Education Standards. In fact, Active Chemistry used the same philosophy of problem-based and inquiry-based approaches that featured Active Physics. It consists of twelve chapters in which each chapter begins with a Scenario or a situation that students can find chemistry in the context of their everyday lives.

All of these COM approaches can be characterized as targeting on high school level studies with an inquiry-based curriculum and with major NSF funding. They also all use an STS philosophy while pursuing personal and community relevance. EarthComm is discussed further in the following section noting some important differences made possible by the completion of the National Science Education Standards (NSES) in 1996. EarthComm was chosen because it was the latest curriculum in science education following the development of the National Science Education Standards (NRC, 1996). So EarthComm became a curriculum that espoused the visions of the Standards, which has been guiding the reform of the US curriculum. Another curriculum reform effort in earth science ongoing in the US is Investing Earth Systems (IES) that aimed at middle school earth science. It was also developed by the AGI with the same philosophy of EarthComm.

Earth System Science in the Community (EarthComm)

The EarthComm project began because of the perceived problem about the Planet Earth and the national deficiency regarding earth science education. Earth science is currently taught in fewer than 10 percent of US high schools (Smith, 1999). In the preliminary survey across the country supported by the EarthComm project, Exline (1998) called this situation an indication of a "second-class" status for earth science in US high schools. He identified several factors which caused this second-class status, including the following:

- Lack of certified professional teachers in the area of earth science;
- Many states lack teacher certification standards for earth science;
- Unavailability of appropriate professional development programs for earth science teachers;
- Inappropriate earth science instructional resources; and
- Many states do not outline requirements for an earth science curriculum.

Several research studies have been conducted concerning this national deficiency in earth science throughout the United States (Mayer et al., 1992; Mayer, 1991; McGinnis, 1991; Woerner, 1991; Matthews, 1968; Ireton, 1994). All of these researchers singled out the lack of qualified earth science teachers as the major problem. Student interest and achievement in earth science decreased because of the lack of qualified earth science teachers and appropriate textbooks (Mayer, 1991). The growing concern and realization of this national deficiency made the EarthComm project possible. Through EarthComm, the American Geological Institute attempts to focus attention on this deficiency in earth science education by developing a complete high-school curriculum in earth science. The EarthComm vision is the teaching, learning, and practice of earth science in all US high schools.

EarthComm is a new national curriculum for high school earth science. The EarthComm project started with a whole new approach to facilitate education about the earth system nation-wide. Seventy-seven teachers of high schools from four areas across the United States (California, Nebraska, Wisconsin, and Tennessee) involving over a thousand students who participated in the field test of the EarthComm program. Unlike other curriculum projects of earth science, the essence of EarthComm is its focus on the visions provided in the National Science Education Standards. It is an attempt to develop an earth science curriculum which matches the visions recommended in National Science Education Standards. This study was undertaken to provide evidence concerning the congruence of the EarthComm curriculum with the visions of reform provided by the NSES. Since the program uses recommendations elaborated in the NSES, it is expected that the visions outlined in the standards would be easily found.

After the advent of EarthComm as an alternative to the traditional curriculum, a study was conducted to examine how the EarthComm program met the visions elaborated in the National Science Education Standards and the effectiveness of EarthComm in stimulating student learning (Park et al., 2004; Park, 2005).

EarthComm and National Science Education Standards

The National Science Education Standards (NSES) for science education have been promulgated to provide a vision of what the science education reforms should be. The standards provide goals for K-12 science education and emphasize new ways of teaching and learning. Shifting from teacher- to student-centered environment prevails through the most categories of the Standards. Most science educators seem to agree about these four goals, but fewer people use them in debates about reforms concerning content and teaching approach (Yager, 2000). The EarthComm teacher's manual (AGI, 2000b) states that EarthComm adopted *inquiry* as one of the major concepts into developing content associated with teaching strategies. As envisioned by the Standards, both content and teaching approach emphasized use of *inquiry*: "*Inquiry* into authentic questions generated from student experiences is the central strategy for teaching science". The Standards suggest that teachers should be skilled to promote *inquiry* by asking questions as well as to guide, focus, and challenge student learning. Not only is *Inquiry* a focus of teaching standards but it is also one of the visions of content standards. *Inquiry* is presented as "a step beyond science as process". This new vision requires that "students combine processes and scientific knowledge as they use scientific reasoning and critical thinking to develop their understanding of science". Thus, science is described as *inquiry* in the content standards. The Standards recommended engaging students in *inquiry* because it helps develop:

- Understanding of scientific concepts.
- An appreciation of "how we know" what we know in science.
- Understanding of the nature of science.
- Skills necessary to become independent inquiries about the natural world.
- The disposition to use the skills, abilities, and attitudes associated with science.

In K-12 science classrooms envisioned by the Standards, the importance of inquiry teaching is presented with the following contrasts (less emphasis on what commonly occurs in classroom to more emphasis on what is recommended by NSES) (NRC, 1996). The foci shifted from teachers' lead in instruction to students' ownership of learning. For instance, the recommendations are students' investigation and analysis of science questions rather than teachers' demonstration, multiple process skills in context rather than out of context, group working to defend conclusions rather than working individually, more investigations to develop values of inquiry rather than fewer activities to leave time to cover large amounts of content, and public communication with whole class rather than private communication with teacher. In these shifts, teachers are challenged to change their teaching approaches from what they used in the past. In addition, they must be continuously required to adapt themselves to new science and technology in order to be successful in teaching. Some research has been reported to support the visions of the Standards after their release. Albert and Jones (1997) studied how the Standards improve teachers' teaching practices through collegial relationships. The major findings indicated that it was the collegial relationship that encouraged teachers to explore, prepare, and implement inquiry activities or tasks for their students.

The key aspect of reform efforts in science education is to make science meaningful and relevant to the lives of all students (Hurd, 1990, 1991, 1994; Yager and Tweed, 1991; McCormick and Yager, 1989; Yager, 1984a, 1984b). Current national science education reform efforts such as those envisioned in the National Science Education Standards (National Research Council, 1996) and the Mammoth Project 2061 sponsored by the American Association for the Advancement of Science (1989) reflect a common direction for science education that would make school science more relevant to the lives of all students.

With the advent of National Science Education Standards, the American Geological Institute (AGI) and National Science Foundation (NSF) initiated and continued to support a new curriculum reform in earth science. Earth System Science in the Community, commonly called EarthComm, is the AGI's high school earth science curriculum project with major support from NSF. The NSES call for the teaching of earth science at all grade levels. Implementing the Standards requires earth science curriculum development and significant reform of the educational system. AGI has focused on these requirements in developing the EarthComm curriculum. In line with the voice of current reform efforts, EarthComm focuses on making science relevant to the lives of students. EarthComm does not deal with as many topics as traditionally included in earth science curricula. It aims to emphasize important concepts, understandings, and abilities that all students can use to make wise decisions, think critically, and understand and appreciate the earth system. The EarthComm vision claims to target the teaching, learning, and practice of earth science in all of the nation's high schools (grades 9-12). With the visions set, the EarthComm goal is the publication and nationwide implementation of a complete high school educational program in earth science that emphasizes earth systems science, inquiry, and community. The program claims to be based on the National Science Education Standards, the results of a 1994 AGI conference on Planning Earth Science Education in the Community, and the 1991 AGI publication Earth Science Education for the 21st Century: A Planning Guide. The EarthComm curriculum includes the aforementioned characteristics unlike other earth science curricula used in domestic and foreign countries.

EarthComm Curriculum Goals

EarthComm emphasizes key concepts, understandings, and abilities that all students can use to make wise decisions, think critically, and understand and appreciate the earth system. The EarthComm program enumerates its goals as the following:

1. To teach students the principles and practices of earth science and to demonstrate the relevance of earth science to their lives and environment.
2. To approach earth science through a problem-solving, community-based model in which the teacher plays the role of facilitator.
3. To establish an expanded learning environment which incorporates fieldwork, technological access to data, and traditional classroom and laboratory activities.
4. To support the development of communities of learners by establishing student teams and by building a greater regional and national community through telecommunication access.
5. To utilize local and regional issues and concerns to stimulate problem-solving activities and to foster a sense of earth stewardship by students in their communities.

Important concepts are stressed in each goal for both teachers and students that coincide with the content outlined with the NSES.

EarthComm's Four Key Concepts

The EarthComm curriculum was designed to offer an earth science course that reflects the current philosophical basis in science education. Four key concepts were chosen and incorporated into the content and structure of EarthComm development: *Relevance, Community, Systems, and Inquiry* (AGI, 2000b; Park, 2003). *Relevance*: Earth science is all about context and relevance. Its goals are to understand the where, when, and how of an artifact or event and to use that understanding to make wise decisions. This broad scope challenges teachers and curriculum developers to make the earth science curriculum manageable for students. In EarthComm, with its earth systems science focus, a chain of connections can be drawn from virtually any earth science phenomena that leads to many other ideas, and eventually back to the students' immediate world. *Community*: EarthComm addresses the earth science instruction through its focus on communities. That means that EarthComm is designed to relate directly to the student's neighborhood, town, state, and region-the student's community from a variety of levels. A community is, in essence, a group of varied living things interacting in some ways. Earth science phenomena affect communities in many and varied ways. The social relevance of earth science, i.e., its role in how communities are designed and how they function, becomes clear through the explicit attention EarthComm gives this concept. *Systems:* EarthComm uses a systems metaphor to develop earth science understandings. In a systems metaphor, the idea that "everything is connected to everything else" is important. A systems approach is more holistic, considering interactions between subsystems. Earth science phenomena are considered as operating within five major subsystems, or "spheres" which interact with and affect each other. *Inquiry*: EarthComm is designed to encourage authentic inquiry. What makes inquiry authentic is that it is focused on asking questions for which the answers are not already entirely known by the students, teachers, or publishers before the learning begins. Inquiry is central to the advancement of both personal and collective scientific knowledge. EarthComm supports this inquiry approach with a variety of activities in each chapter. Some are open-ended, some place the students in the position of interpreting data, some help to illustrate phenomena so that students can assess the impact the phenomena might have on their communities

EarthComm Curriculum Content and Structure

Hundreds of teachers, scientists, and students have helped produce EarthComm. In the summer of 1998, teams of earth science educators wrote 122 inquiry-based investigations. EarthComm chapters were reviewed by teachers and scientists, revised, and then pilot tested by 35 teachers in the spring of 1999. Seventeen teachers from the National Earth Science Teachers Association collaborated with project staff to revise EarthComm in the summer of 1999. EarthComm underwent a national field testing in the 1999-2000 school year.

The EarthComm content (Park, 2003) is selected on the basis of related components recommended in the Content Standards of the National Science Education Standards. Each chapter provides activities associated with related content. The suggested Content Standards include: 1) Unifying Concepts and Processes, 2) Science as Inquiry, 3) Fundamental Understandings in Earth and Space Sciences, 4) Science and Technology, 5) Science in Personal and Social Perspectives, and 6) History and Nature of Science. The teacher's guide for EarthComm provides a summary of how the EarthComm modules and chapters were correlated to each component proposed by the Content Standards. EarthComm deals with most of the recommended Content Standards except for a weakness in dealing with "Science and Technology" and "Science in Personal & Social Perspectives" (AGI, 2000b). In relation to content teaching, the EarthComm curriculum uses four main teaching strategies: Detect and Reflect Engagement, Guided Inquiry Activities, Global Issues, and Authentic Inquiry. The Detect and Reflect component encourages students to detect and reflect on how the unit topic is linked to their daily lives, society at large, and environments (local, regional, national, and global). It is designed to motivate students to identify with the topic and want to study it more in relation to their wants, needs, conceptions, experiences, and reactions. Content is introduced at the level of public news media. The Guided Inquiry Activities introduce EarthComm content from a constructivist perspective that integrates phases of the learning cycle, attention to multiple intelligences and learning styles, opportunities for guided applications, and design of authentic inquiry plans. Students analyze and evaluate each unit topic relative to five modules or units. They are Earth's Dynamic Geosphere; Understanding Your Environment; Earth's Fluid Sphere; Earth's Natural Resources; and Earth System Evolution. Students define a local issue or problem related to the unit topic, design a research plan to investigate it, conduct their research and form inferences, summarize and present their research and inferences, and suggest ideas and bases for additional inquiry. Each module within EarthComm consists of three chapters connected to a common theme. It is intended that the modules and chapters be taught in any sequence. Every chapter begins with a challenge that sets a community-based context and which requires that students extract key ideas and understandings from the chapter activities as they address a fundamental scientific problem or issue. For example, within a chapter entitled "Volcanoes and Your Community" students are asked to evaluate the likelihood of their community being affected by a volcanic eruption. Students use their investigations in the chapter to prepare a geologic report to help their local government decide whether or not to devote funds to an emergency evacuation and safety plan. Each chapter offers options for students to pursue extended group inquiries and each chapter promotes whole-class inquiry on the unit theme. Further, students are asked to discuss about scientific knowledge as a human endeavor and in historical perspectives so that they are motivated to think about how we know what we know about the Earth or the nature.

In constructing content components included in EarthComm, traditional divisions (geology, meteorology, oceanography, and astronomy) of earth science content are avoided. Instead, ten big ideas are presented such as energy in the earth system, origin and evolution of the universe (AGI, 2000a). These components of big ideas were incorporated into establishing goals as well as curriculum content of EarthComm. The EarthComm program develops a comprehensive program encompassing earth system science as recommended in NSES.

Each of the EarthComm chapters follows the 5-E lesson model: engage, explore, explain, elaborate, and evaluate. Trowbridge et al. (1999) presented the 5-E learning cycle in "Becoming A Secondary School Science Teacher" as an effective instructional model that is consistent with a constructivist approach to learning. In the model students encounter phenomena experientially (engage, explore) prior to having general rules stated that help them articulate underlying principles (explain). Then the skills and new knowledge are transferred to new situations (elaborate) and/or have their understanding enriched through additional experiences. Student readiness to make meaning of additional experience is assessed (evaluated) before the cycle begins again.

EarthComm Teacher Enhancement Program

Attaining the vision and goals of EarthComm requires changes at many levels of the educational system including schools. Among the levels, helping the teachers who must accomplish classroom-level reforms is critically important. Recent figures indicate that as few as 5% of 12 million high school students in the US enroll in a first-year earth science course (Smith, 1999). With funding from the Exxon Education Foundation, the EarthComm project initiated a two-phase national teacher enhancement program. The 1998 pilot phase engaged 90 participants (teacher-administrator teams) from a variety of school settings at enhancement workshops held by four Universities: Nebraska Earth Science Education Network-University of Nebraska, Lincoln; Bay Area Earth Science Institute-San Jose State University; Center for Mathematics and Science Education-University of Wisconsin, Milwaukee; and Department of Geology-Georgia State University. Workshop leaders and independent evaluators assessed the abilities/needs of participating classroom teachers in terms of inquiry teaching, content knowledge, and understanding of the systems approach to earth science. Workshop teachers were introduced to sample EarthComm curriculum materials, the EarthComm inquiry and systems approach was modeled and discussed, and relevant content was provided by earth scientists. An evaluation of the pilot phase was completed by the summer, 1999.

EarthComm Curriculum Field Test

The EarthComm project began its field-testing of five modules in 77 schools across the nation in the summer, 1999. The aforementioned four Universities were chosen as EarthComm Field Test Workshop Centers. Each workshop site conducted a seven-day workshop involving a total of 77 high school teachers. The workshop was for volunteer teachers who came from the various levels of the school environment. Distribution of size of classes, location of schools, and even years of teaching experience of the teachers illustrated the diversity of the sample of teachers and schools.

Research on EarthComm Curriculum Analysis

Two studies were conducted on how different and effective EarthComm curriculum was. First study was to investigate the Earth System Science in the Community (EarthComm) curriculum in terms of its effectiveness in improving student learning (Park et al., 2004). Since EarthComm was developed and interwoven with visions in the National Science Education Standards (NSES), the study investigated how NSES went along with this new EarthComm curriculum. Data gathered from field-testing EarthComm Modules I and II were analyzed to find any significant changes between pre- and post- tests. The major findings were: 1) Student learning was enhanced by EarthComm when taught by teachers whose philosophy agreed with the NSES. Conversely, student scores were not significantly increased in classrooms of teachers whose philosophy was not in agreement with the NSES visions; 2) EarthComm does not significantly impact student achievement in terms of school size and the type of community (urban and rural) in which the school is located; 3) The differences in student achievement scores between the highly experienced teachers and new teachers are not statistically significant for Module I test while significant for Module II; 4) Student higher-order thinking skills are significantly improved in EarthComm classes. These findings indicate that EarthComm provides a needed program in earth science to meet the visions of the NSES (Park, 2001).

Looking at the teachers who participated in the field test of Module I, eight teachers (N = 8) were identified as being highly supportive of teaching and learning closely aligned with visions in the NSES. They were T2, T3, T4, T6, T7, T14, T20, and T21. On the other hand, there were six teachers (N = 6) who weakly supported visions in the NSES in Module I. They were identified as T1, T10, T15, T16, T23, and T24. These results are presented in Table 1. For the group of teachers who highly perceived the Standards recommended in the NSES, a mean of their student scores in the pretest ranged from 6.00 to 11.54 while mean posttest score ranged from 9.25 to 17.05. Particularly, student achievement scores for T2, T4, and T6 are noted. All teachers were identified as highly supportive of the Standards envisioned in the NSES. On the other hand, a range of low means (6.83-9.14 for the pretests and 8.00-11.06 for the posttests) was recorded for the teachers who weakly espoused the NSES visions. In this group, only slight changes were observed regarding student achievement even after they had experienced the EarthComm

Table 1. Student data for two groups of teachers who strongly support and weakly support the NSES teaching standards for module I

Group	Teacher	Student Pretest		Student Posttest	
		Mean	SD	Mean	SD
Strongly Supportive Group (N = 8)	T2	9.49	2.78	15.00	1.97
	T3	11.54	2.76	14.00	2.22
	T4	10.76	2.74	17.04	3.04
	T6	9.57	3.08	17.05	2.97
	T7	8.10	3.56	11.09	2.27
	T14	10.07	3.75	13.53	2.68
	T20	6.00	1.87	9.25	4.44
	T21	8.90	3.02	12.86	2.73
Weakly Supportive Group (N = 6)	T1	9.14	2.71	11.06	3.43
	T10	7.86	2.44	9.46	3.46
	T15	8.52	3.09	9.72	2.98
	T16	8.58	4.05	10.71	4.45
	T23	6.83	2.87	8.00	3.10
	T24	7.82	2.16	8.37	2.64

(Excerpt from Park et al., 2004)

lessons (Park et al., 2004).

The difference between the strongly and weakly supportive groups is significant at the 0.05 level. The difference between pre- and post- test within each group is highly significant ($P < 0.001$), and the interaction is also highly significant ($P < 0.001$). The mean of all student scores for the group of teachers who highly espoused visions recommended in the NSES was 9.30 ($SD = 1.70$) for the pretests and 13.73 ($SD = 2.71$) for the posttests. This outcome indicates that EarthComm significantly increases student achievement ($t = 6.99$) when taught by teachers who strongly agree with the teaching envisioned by the developers and the NSES (Park et al., 2004).

Six field-test teachers ($N = 6$) who taught Module II were highly supportive of the NSES Standards. They were coded as T2, T3, T4, T6, T7, and T29. Four field test teachers ($N = 4$) who taught Module II weakly supported the Standards of the NSES. They were identified as T1, T28, T30, and T31. Table 2 reports the mean scores for students on the pre- and post- tests. For the group of teachers who strongly supported visions of the NSES, the mean of pretest scores for their students ranged from 5.30 to 10.09 while mean posttest scores spread 5.76 to 17.70. Among the group of 10 teachers involved with teaching Module II, achievement scores for T2 and T6 were particularly outstanding. Student scores in the posttest for T2 and T6 exceeded by far those in other classes. According to the project manager's documented comments, T6 is "a very accomplished teacher with several teaching awards and is well-versed concerning the NSES" and T2 has "a good philosophical understanding of inquiry-based learning… My impression is that he is more in line with the NSES than nearly all the others" On the other hand, for the group of teachers who weakly espoused visions of the NSES, the mean pretest score of students ranged from 5.55 to 7.89 while mean posttest score was from 6.00 to 8.86. Little improvement in student achievement was found in this group following the implementation of EarthComm (Park et al., 2004).

The difference between the two groups of teachers is significant at the 0.05 levels; the difference between pre- and post- test is highly significant ($P < 0.001$); and the interaction is also highly significant ($P < 0.001$). The mean of all student scores for the group of teachers whose beliefs weakly matched the Standards included in the NSES was 7.37 ($SD = 2.93$) for the pretests and 6.87 ($SD = 2.49$) for the posttests. The mean actually decreased after the implementation of EarthComm. This result indicates that student achievement was not significantly increased ($t = -1.00$) in the class of the teachers who weakly supported the Standards recommended in the NSES. On the contrary, the mean of all student scores for the group of teachers who strongly supported visions in the NSES was 7.55 ($SD = 3.02$) for the pretests and 13.71 ($SD = 5.43$) for the posttests. This outcome indicates that EarthComm significantly increases student achievement ($t = 16.54$) when taught by teachers who strongly agree with the teaching envisioned by the

Table 2. Student data for teachers for module II who agreed with the teaching standards addressed in the NSES

Group	Teacher	Student Pretest		Student Posttest	
		Mean	SD	Mean	SD
Strongly Aligned with NSES (N = 6)	T2	7.31	2.77	17.70	3.48
	T3	10.09	2.67	11.47	3.28
	T4	6.39	2.52	7.11	3.14
	T6	6.31	2.53	16.54	3.84
	T7	5.39	2.25	7.39	3.58
	T29	5.30	1.86	5.76	1.75
Weakly Alligned with NSES (N = 4)	T1	7.89	2.71	6.00	2.60
	T28	6.39	2.52	7.11	3.14
	T30	6.59	1.87	8.86	2.98
	T31	5.55	2.16	7.73	2.28

(Excerpt from Park et al., 2004)

Table 3. Comparison of general features for all pages included in the three selected earth science textbooks

Features	EarthComm (964 pages)		Korean Earth Science (463 pages)		Holt Earth Science (714 pages)	
	Number	Percent**	Number	Percent**	Number	Percent**
Units	5	0.5%	8	1.7%	8	1.1%
Chapters	15	1.6%	17	3.7%	30	4.2%
Topics*	120	12.5%	155	33.5%	273	38.3%
Laboratory Activities	84	8.7%	15	3.2%	40	5.6%

*Unit is consists of chapters. Chapter is consisted of topics. Topic means sub chapter headings. Use of these terms is, for instance, Oceans (Unit), The Ocean Basins (Chapter), Features of the Ocean Basins (Topic), and Continental Shelf (Concept).
**Demonstrated percentage means only a portion per page of each book. For instance, units of EarthComm are 5. The percentage of 0.5% is calculated as follows: $(5/964) \times 100 = 0.5\%$. This method is used to compare features of each curriculum. Thus, the percentage does not necessarily come to 100% in total because it represents only a ratio of a portion of each feature (Park, 2005, pp. 542).

NSES (Park et al., 2004).

A second study investigated the differences between EarthComm curriculum that was based on the National Science Education Standards and curricula following two conventional textbooks (Park, 2005). Now that EarthComm has been completed and available from a publisher at the end of year 2000, it is appropriate to review it and to compare it with other textbooks which did not have the National Science Education Standards to provide visions for reform. Earth System Science in the Community (EarthComm) and the "most used" high school earth science textbooks in the United States and Korea were analyzed in terms of general features, questioning style, and level of laboratory activities by two experts using Textbook Questioning Strategies Assessment Instrument and Herron's four levels of activities. The inter-rater reliability varied from 0.91 to 0.97 for questioning style depending on each individual book and 0.99 for laboratory activities. The results showed that the standards-based curriculum EarthComm included the largest number of pages and laboratory activities with the least number of chapters and concepts among the three textbooks compared.

The standards-based curriculum included by far more questions and the largest percentage of experiential questions compared to both of the most-used traditional textbooks. Non-experiential questions tend to be "open-ended" in standards-based curriculum, "direct information" in the Korean textbook, and both "open-ended" and "direct information" in the most used US textbook. Higher-order questions are featured in standards-based curriculum, which call for inferences and application. These findings explicitly stress that high school earth science textbooks should be inquiry-oriented in teaching and learning.

Conclusion

The COM curricula including ChemCom, Active Physics, BioCom and EarthComm in school science are the products of the US curriculum reform efforts in which science learning is emphasized with relevance, inquiry, and local community. The goals

Table 4. Comparison of the types of non-experiential questions included in a sample from the three selected earth science textbooks

Textbooks with Sample Pages	Rhetorical	Direct Information	Focusing	Open-ended	Valuing
EarthComm	0.2%	3.0%	0.0	17.2%	1.0%
Korean Earth Science	6.9%	79.3%	0.0	6.9%	0.0
Holt's Earth Science	3.4%	32.9%	0.0	45.5%	0.0

(Park, 2005, pp. 543)

and instructional philosophies of these new curricula are based on the visions of the National Science Education Standards. Research showed that the newly developed science curricula brought in changes to improve student learning in a meaningful way. In-depth discussion of EarthComm curriculum, for instance, implied the followings for science education reform.

1. Reform visions of the National Science Education Standards are critical. Goals, instructional philosophies, content, and assessment of each curriculum are line with NSES. Curriculum developers or teachers should consider the issues and implications when they select and teach in ways that coincide with the NSES visions.

2. Teacher's philosophy aligned with NSES is highly correlated with student achievement. Utilization of EarthComm results in improved student learning about the Earth. In other words, EarthComm may not help in developing the same degree of student understanding about the Earth unless the teachers understand and agree with the visions recommended in the National Science Education Standards. Teacher professional development program produced teacher understanding about EarthComm and prepared for teaching it. This kind of investment for teacher learning ultimately results in having a great impact on student learning (Greenwald et al., 1996). Teachers believe that their behavior will result in the student learning that they desire and value (Haney et al., 1996; Crawley and Koballa, 1992). Understanding of the belief structures of teachers has been found to be important for improving teaching (Pajares, 1992).

3. Teacher professional development workshop is necessary in order for the reform to be successful. EarthComm research, for instance, clearly point to the fact that teachers need to be trained and supportive of the visions elaborated in the NSES in order for EarthComm to be successful. With teacher professional development program in place, it is suggested that whoever would try to adopt this curriculum either in Korea or other context of countries needs to understand the philosophy and the context of the development. Education is basically a product of culture. Therefore, modification or adjustment process is necessary to make a new curriculum fit to the context of teaching.

The COM curriculum is unique in its goal, instructional philosophies and assessment. Teachers who want to teach COM curriculum should be invited to a workshop or training sessions to understand the visions and standards elaborated in the NSES on which the goals and philosophy of instructional strategies are based. This way the goals of the COM curriculum would be accomplished as designed and hoped for making all the students scientifically literate in the 21st century.

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