Implementing EarthComm: Teacher Professional Development and Its Impact on Student Achievement Scores in a Standards-Based Earth Science Curriculum

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Introduction

With the advent of National Science Education Standards (NRC, 1996) and Benchmarks for Science Literacy (AAAS, 1993), science education in the United States is undergoing a major curriculum reform. Earth System Science in the Community (EarthComm) was born in the midst of this new curriculum reform movement. New science curricula have been developed in response to new research information. For example, 'Chemistry in the Community' was developed in 1988, 'Biology in the Community' in 1996, 'Active Physics' was developed and published in 1998. The main focus of these newly developed programs is on the relevancy of science to students' lives through inquiry-based science instruction. Such changes are major characteristics of the current reform in science education and exemplify the goals for science espoused in the National Science Education Standards (NSES). With the visions of NSES embedded, Earth System Science in the Community (EarthComm) was developed and published in 2001.

This type of vision for science calls for fundamental changes in the content and pedagogy of K-12 science curriculum. Furthermore, the NSES visions propose shifts in the teaching and learning, the way in which teachers assess, and what it means to know science. These shifts are a function of a new science curriculum which requires teachers to rethink their previous beliefs and practices. In order for this reform vision to be actualized in classroom practice, teacher change must take place. Acceptance of this vision requires a considerable amount of change in teachers' teaching and practices

(Fullan and Miles, 1992; Battista, 1994; Haney, Czerniak, and Lupe, 1996; Ball, 1997; Spillane and Zeuli, 1999).

Teacher professional development continues to suggest that these changes can be achieved through the implementation of research-based practices and consequently improve student learning (Guskey and Sparks, 2004; Little, 2004). However, researchers contend that there were gaps in our understanding about the relationship between teacher professional development and student learning. It is pointed out that there is lack of understanding about the relationship between teacher professional development and the deeper issues of curriculum and learning (Cohen and Ball, 2001; Little, 1994) and a paucity of understanding about the relationship between teacher thinking and student learning (Sprinthall, Reiman, & Thies-Spinthall, 1996; Cohen and Ball, 2001). Thompson and Zeuli (1999) reported that teachers rarely understood the "deep intent" of professional development reforms. Although the NSES visions call for a conceptual change in teachers' understanding of subject matter, teaching and learing, many teachers' thinking tends to remain unchanged. Reiman (2004) addressed the complexity of relationship between professional development and student learning: "We do not understand how professional development affects student learning…the strange thing about teacher professional development is that everyone thinks they understand it… teachers participated in educational programming for the purpose of learning more about their subject, or about students, or about classroom management, or about teaching practices. Then they return to their classrooms and attempt to integrate what they have learned into their teaching. But it is not so simple (p.4)."

These concerns demonstrate the centrality of understanding about how teacher professional development affects student learning. Without understanding the importance of teacher changes as the process on which student learning is impacted, reforms of teacher professional development would continue to be ineffective. If it is true that teacher thinking developed through the teacher professional development influences student learning, then change in the teacher thinking becomes critical in enhancing student learning.

Research Question

Although researchers reported positive results with reform-based curricula and reform strands in school science (Clough, 1994; Haney, Czerniak, and Lupe, 1996), the proposed changes for the teacher in science education reform were not given full consideration. Neither has it been known specifically how teacher thinking impacts student achievement in the context of standards-embedded new science curricula. A cohort of teachers completed a week-long professional development program in which information for EarthComm implementation was provided. This study investigated the teachers' thinking about the reform visions of the NSES delivered by EarthComm teachers and how their thinking impacts on student achievement scores. The following questions guided this investigation: 1) What are inservice teachers' philosophies about science teaching and learning after the professional development on EarthComm and 2) How does their change in thinking impact on student achievement scores?

Most often student learning outcomes include indicators of student achievement, such as assessment results, portfolio evaluations, marks or grades, or scores from standardized examinations (Guskey and Sparks, 2004, p. 15). We chose student scores on EarthComm Module Tests as indicators of student learning in the study.

EarthComm and NSES Standards

Earth System Science in the Community (EarthComm), a high school earth science curriculum developed by the American Geological Institute funded, in part, by NSF, seeks to increase scientific literacy among all levels of students and to produce a citizenry that understands the "big ideas" about our planet and its history. The need for reform of Earth science education is particularly acute. Fewer than 10% of the nation's high schools provide earth science courses. Exline (1998) described the status of Earth science as "second-class" and pointed out several factors that contribute to this situation: 1) lack of certified professional teachers 2) lack of teacher certification standards in many states 3) lack of appropriate professional development programs for earth science teachers and 4) inappropriate earth science instructional resources. The growing realization of this national deficiency made the EarthComm project possible. The National Science Education Standards presented a vision of what science education in K-12 schools should be. Among the visions of NSES, themes adopted in developing EarthComm are *inquiry* (p.23), *relevance* (p.104), *systems* (p.116), *community* (p. 45), and *professional development* (p.57) – note: although these characteristics are explained more than once throughout the NSES Standards, the page number in each parenthesis is a typical one. These components of visions were infused into EarthComm curriculum.

- *Inquiry*-NSES stress the importance of the scientific investigation throughout the Standards. Scientific inquiry is a multifaceted activity that involves many skills, as well as a lot of creativity. Skills such as observation, question posing, and others are important to scientists, but these do not necessarily occur in any pre-determined order in an investigation. EarthComm incorporates inquiry through the "Chapter Challenge" component of each chapter. The challenge functions throughout the chapter as a motivation to ask how the earth science ideas that are being learned relate to the specific communities the students are considering. 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—but all support the emphasis on inquiry-based learning.
- *Relevance*-National Science Education Standards call for a change in emphasis from learning science content areas "for their own sake" to learning in ways that makes science relevant in personal and social perspectives. In EarthComm the concept of relevance permeates the curriculum, but becomes particularly explicit as each chapter is introduced, and is maintained through the attention given to the Chapter Challenge.
- *Systems*- NSES recommend a systems approach to organize content. Its goal is to think and analyze in terms of systems. EarthComm uses a systems concept to develop earth science understandings including interactions between subsystems.
- *Community*- NSES envision the Content Standards adapted to community needs in curriculum design. EarthComm activities relate directly to the student's neighborhood, town, state, region, and so on—the student's community taken at a variety of levels.

• *Professional Development*- NSES suggest that teachers must be involved in the development and refinement of new approaches to teaching, assessment, and curriculum. EarthComm produced lead teachers through a teacher professional development institute so that they can train other teachers.

One facet provides guidance about what an exemplary Earth Science program should entail. The NSES call for the teaching of earth science at all grade levels. Certainly, implementing the Standards requires the development of new earth science curricula and significant reform of the educational system. Along with the current reform efforts of curriculum development, EarthComm also focuses on making science relevant to the lives of students. EarthComm does not cover as many topics as the traditional high school earth science textbook. Instead it emphasizes important concepts, understandings, and abilities that all students can use to understand and appreciate the earth system. The EarthComm vision is to expand and improve the teaching, learning, and practice of earth science in all of our nation's high schools (grades 9-12).

Teacher Professional Development Workshop

All the field test teachers participated in a week long workshop. Following suggestions made during the conference of workshop administrators at the American Geological Institute (AGI), the workshop was designed and conducted for the field test teachers to become immersed in the design characteristics and innovative features of the EarthComm curriculum. The week-long workshop covered many topics, issues, and concerns related to effective science teaching and learning, curriculum design and field testing. The workshop started with a general overview of the workshop and the EarthComm curriculum. The first session included an overview of the National Science Education Standards. The remaining workshop sessions each had particular pedagogical focus. Each of the pedagogical foci was linked to an instructional component of the EarthComm curriculum. This linkage between pedagogy and curricula served to not only provide participants with the theory or rationale behind the design and intent of the curricula, it also allowed for the participants to glean an overview of the curricula's instructional model. The model is based on sound constructivist based ideas of content delivery. This model was discussed in terms of the theoretical underpinnings of constructivism, the relationship between the constructivist philosophy and hands-on instruction, and the relationship to the Teaching Standards in the National Science Education Standards. This discussion was carried out using the curriculum as the vehicle to deliver the pedagogical content – in this particular case, aspects of Module I, Volcanoes and Your Community. In other words, the discussion took place using concrete examples of activities, within a chapter of EarthComm, that were based on the model. Pedagogical content was delivered using the EarthComm curricula as the instructional vehicle. Other sessions were devoted to topics such as thematic instruction, teaching to multiple learning styles, cooperative learning and alternative assessment. Aligned with these topics were instructional issues specific to the EarthComm curricula. For example, teachers practiced with the delivery of numerous activities. Teachers who were selected to field test certain units worked collaboratively and immersed themselves into the activity from both a teaching and learning perspective. Teachers were allowed time to work as teams in gleaning an overview of particular chapters and then performed some of those activities and presented summaries of chapters and activities to the entire group. To promote the use of local resources, activities were performed that served to utilize local resources. For example, Chapter 2 has seismographs activities that were discussed in conjunction with a local seismograph laboratory. A field trip to explore local geological formations aided in the discussion of the content numerous chapters devoted to geological land forms. All the while, as teachers participated in these activities, ties to the EarthComm curriculum were emphasized and discussed in terms of how the teachers use a variety of resources to support the implementation of the curriculum. A week-long workshop ended by providing lines of communication including Webboard, emails, and online web homepage to ensure a continuous line of communication and feedback between all parties including participants and project personnel.

Flow of Teaching Activity in EarthComm Classes

Basically, all the chapters of EarthComm are structured with a variety of inquiry-based activities. Module I contains three chapters and 17 activities about Earth's Dynamic Geosphere whereas Module II has three chapters and 18 activities about Understanding Your Environment. Modules I and II were field tested for this study. All the activities are designed with the 5-E learning cycle model in which inquiry skills are promoted. Activity begins with *Chapter Challenge* (Engage) where students read and discuss a scenario that presents a community-based issue to solve through Earth Science and Inquiry. Teachers allow students to share their current thinking openly without a closure. Second is *Think About It* (Engage) where students answer open-ended questions that set the context for an activity and provide the teacher with a pre-assessment of students' ideas. Teachers allow students to share their ideas openly. Third, *Investigate* (Explore) in which students collaborate on an inquiry activity that requires hands-on work, literature or web research, or fieldwork. Fourth is *Reflecting upon the Activity and the Challenge* (Explain). In this stage, students read a brief summary of the main ideas explored in the investigation and their relationship to the chapter challenge. Fifth, *Digging Deeper* (Explain) lets students read text, illustrations, and photographs that explain concepts explored in the investigation. Terms are defined and clarified here. Teachers provide further information and clarification of concepts through lecture, slides, videos, or laser disk presentations. Sixth is *Understanding and Applying What You Have Learned* (Elaborate). Students respond to questions that check their understanding of key principles and concepts (learning goals) for the activity. Teachers review student responses and use the questions to further probe and hone understanding of key learning goals. Seventh is *Preparing for the Chapter Challenge* (Elaborate/Evaluate) in which students put their investigative results into the context of the challenge by preparing or organizing their work as it relates to their final products. Teachers review student performance in terms of its consistency with criteria. Eighth is *Inquiring Further* (Elaborate/Evaluate). Students are presented with options for deepening their understanding within the activity whereas teachers promote and encourage further inquiry. At the end of the activity, students present their conclusion to the Chapter Challenge and teachers use the assessment criteria to assess the extent to which student work demonstrates mastery of concepts and skills. With laboratory activities and questioning strategies stressed in every class of EarthComm, it is notable that the NSES visions remain as a main structure of lessons.

Method

<u>Sample Selection: Field-Test Teachers and Students</u>

Forty EarthComm field test teachers (N=40) reported student achievement scores from Module I (N=24) and Module II (N=16). However, nine teachers (N=9) were involved with field-testing both Modules I and II. Thus, the sample for this study included 31 (24+16-9) high school teachers. These 31 teachers came from a variety of science teaching backgrounds including biology, earth science, physics and teaching experiences ranging from 2 to 33 years. They were also employed in different communities in South and West and Midwest in the United States, including both rural and urban areas. Thirty one teachers were all participants in the Leadership Institute of Professional Development for 5 days long during the 1999-2000 school year. The major components of the Institute program include EarthComm goals and expectations for Teachers and Students, EarthComm introductory information, key concepts (relevance, community, systems, inquiry) connecting to NSES activities, curriculum structure with explanation and activities of modules & chapters, 5-E learning cycle, curriculum design, EarthComm “Big Ideas,” assessment issues such as integrative thinking, importance, flexibility, and consistency, and professional development workshop planning information with detailed strategies. After the 5 days of Leadership Institute program, the forty teachers went back to their schools and taught more than 14 activities on average in Module I and II respectively. For Module I, around 950 students participated in the study in 24 classrooms with an average of forty students per class. On the other hand, the Module II field test involved 428 students from 16 classrooms with an average of 27 students per class. The overall pool of students came from a variety of backgrounds in terms of socioeconomic status, school size, and school location. Although the study sample did not completely represent all major geographic areas of the United States, they were widespread enough to signify an extensive range of students.

<u>Instrumentation</u>

Student Achievement Test

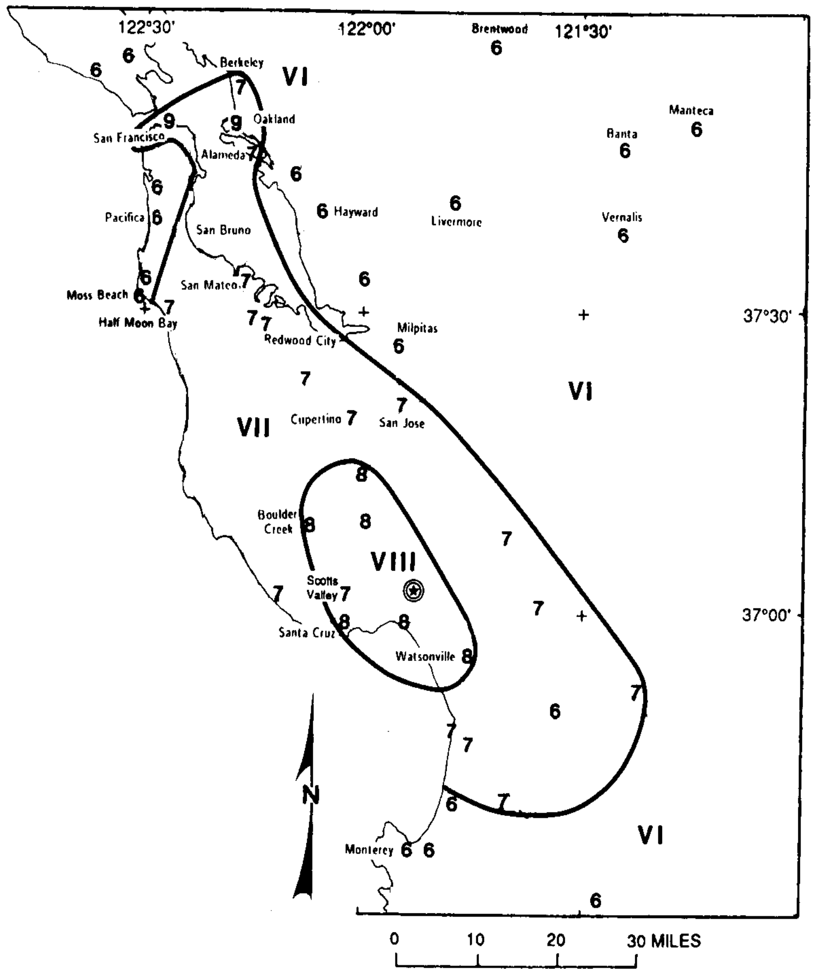
Tests with items developed separately for Modules I and II were designed to study improvement of student performance. American Geological Institute staff and an independent evaluator developed the test items specifically to evaluate the EarthComm program. The test items were written by one independent evaluator using New York Regents Exam and the AGI/NSTA High School Earth Science Exam that align with the objectives of the Module I and II. Three of the AGI staff including another evaluator and two co-authors reviewed the developed items. Both tests for Modules I and II included 23 multiple choice questions that promote applying what the students learned to their local community’s needs that characterized the NSES recommendations (relevance, systems, community, and inquiry). This test was administered to students by classroom teachers before and after the implementation of both EarthComm modules in each classroom. The reliability (KR-20) for Module I is r=0.55. The mean difficulty of the test was 39.09 with a low mean discrimination index (0.30). This means that 39 % of all students on average could be expected to get correct answers when they completed. The discrimination is the correlation of the item score with the total test score. A value of mean discrimination index 0.30 for the test means that there is a 0.30 correlation between scoring well on the given item and scoring well on the test as a whole. On the other hand, the reliability (KR-20) for Module II is r=0.52 and 34.74 for mean difficulty, and 0.29 for mean discrimination.

Samples of the questions for Module tests are presented below. The questions' foci in Module I and II tests center on relevance, community, and inquiry application.

Question Sample 1:
On a walk in your community, you find rock exposures made of fine-grained basalt and small pieces of pumice along the trail. What can be inferred about volcanic activity in your community from the presence of these rocks?

(A) Your community is now at risk from active volcanic activity.
(B) At some point in the past, basalt and pumice erupted at the same time in your community.
(C) There has been volcanic activity both at and near your community in the past.
(D) Most of the igneous activity near your community occurred deep underground (plutonic or intrusive).

Question Sample 2:
The map below shows the distribution of earthquake intensity for the Loma Prieta earthquake (October 1989). Which of the following might explain why there were regions of highest intensity in San Francisco and Oakland, far from the epicenter near Santa Cruz?



(A) Multiple earthquakes occurred with different epicenters but scientists were not able to distinguish among them.

(B) Few people live in the part of California near the epicenter, so intensity measurements are inaccurate in that vicinity.

(C) The building codes in San Francisco and Oakland do not require as much earthquake resistance as those near Santa Cruz.

(D) The areas with the highest intensities represent areas underlain by soft sediment and landfill which amplify the shaking from an earthquake.

Data Collection

Teacher Thinking

In order to determine teachers' change in their thinking about the NSES visions (Research Question 1 and 2), two kinds of data were collected and ensured the reliability:

• Data I- evaluation provided by Project Manager of the EarthComm Field Test regarding each teacher's thinking about teaching, which included onsite observations, interviews, and personal communications (see next section for details).

• Data II- use of the EarthComm Field Testing Feedback which included a series of teacher surveys of the teachers' feedback regarding their reflection on the field test of EarthComm Modules I and II (see next section for details).

The data collection for Data I, however, is limited in terms of several factors as follows: 1) Participation in the field test does not automatically indicate an understanding of the NSES. 2) Furthermore, it is doubtful that the Teacher Surveys (teachers' comments in general) solely reflect teaching thought. 3) Teacher-related variables, particularly -level of frustration, may have also impacted findings, such as discontentment with school administration and colleagues; difficulty adhering to school, district and/or state curriculum mandates; lack of material resources; lack of institutional support; philosophical, emotional and/or disciplinary conflicts with students; etc. These types of factors demonstrate that the nature of teacher thinking does require a deeper level of understanding and needs to be stratified into groups of teachers to measure up the teacher impact on student learning. Thus the project manager's observations about each teacher become meaningful data to this purpose and became indeed pivotal in understanding individual teacher's teaching practice and beliefs because he typically worked closely with the teachers during the whole period of the project. This need became evident from one of the EarthComm project manager's comments through his onsite observations:

> *I know for a fact that several teachers had circumstances external to their "ideal" teaching philosophy affect their classroom performance. Since some of our EarthComm schools are situated in inner cities, I see the teachers struggle so much with their school environments.*

So this study considered these circumstances with the data about teachers' philosophies collected from the survey of Data II (see next page for details).

Data II were collected with the EarthComm Field Testing Feedback. Teachers' feedback was gleaned during the field testing of two modules. This information is instrumental in understanding the degree of teachers' support and advocacy since some of the questions directly asked to how they understand and support the NSES.

Data I

Particularly, the project manager during the field test period was very clear about his experiences and conversations with each teacher when responding to the classification scheme used and suggestions about features of a ‘strong’ and ‘weak’ group in terms of support. Examples of the project manager’s comments are summarized in each group as follows.

Examples of Project Manager Comments	
Strongly Supportive Group	Weakly Supportive Group
- *Teacher 1* is a very accomplished teacher and well-versed in the NSES - *Teacher 2* has an understanding of the NSES. She also has a teaching style/belief that she was able to superimpose upon the curriculum. - *Teacher3* has a good philosophical understanding of inquiry-based learning. He is more in line with the NSES than others, but simply lacked experience (as most teachers do) in implementing an inquiry-based curriculum.	- *Teacher 1* did have negative reactions to some of the EarthComm approaches. This may indicate that his experience did not complement the EarthComm approach. - *Teacher 2* - There are indications that her teaching belief didn't match EarthComm concepts well. - *Teacher 3* changed some activities to more closely follow her own teaching style. Her "belief" may indeed be different from that used by EarthComm.

To communicate clearly with the project manager who works with all of the field-test teachers, we provided him with a set of criteria of strong support and weak support group so that he could utilize those criteria when making onsite observations. The 12 characteristics of the criteria were selected from the NSES Standards including changes envisioned by teaching standards (p.52; items 1, 2, 3), professional standards (p.72; items 4, 5, 6), assessment standards (p.100; items 7, 8, 9), and content standards (p.113, items 10, 11, 12). On average three changes were selected from each standard by the two experts in terms of relevancy to the environment of EarthComm science teaching and learning. Those characteristics basically represent changes of science teaching and learning envisioned by the NSES that are summarized in the following table.

Characteristics of Strong and Weak Support for the NSES	
STRONG SUPPORT	WEAK SUPPORT
1. Providing opportunities for scientific discussion and debate among others	Asking for recitation of knowledge and facts
2. Continuously assessing student understanding	Often testing students for factual information
3. Focusing on student understanding and use of inquiry processes	Focusing on student acquisition of information
4. Use of Inquiry into Teaching and Learning	Frequent use of lectures to teach knowledge and skills
5. Collaborative learning during class	More of individual learning
6. Student learning through investigation	Student learning by reading and lecture
7. Assessing understanding and	Assessing discrete knowledge

reasoning	
8. Assessing achievement and opportunity to learn	Assessment only achievement
9. Students are engaged in ongoing assessment	Assessment only by teachers
10. Studying a few fundamental science concepts	Covering many science topics
11. Emphasis on understanding scientific concepts and analyzing questions	Focus on scientific facts and information
12. Often communication with science explanations and arguments	Providing answers to questions about science content rather than discussing

Data II

Some of questions as part of the EarthComm Field Testing Feedback presented teachers' direct response to the degree of their support for the NSES. The following questions were used to determine teacher support and in turn make groups:

Question 1: Do you personally agree with kinds of teaching that the National Science Education Standards advocate? If yes, rate the degree to which you agree with the standards.

1 ______: _______________: _______: __________________: ________ 5
Agree   Agree somewhat   Neutral   Disagree Somewhat   Disagree

Question 2: How much do you think your current teaching practices are in line with the NSES? Please elaborate!

Question 3: Explain how you incorporate these core concepts of EarthComm into your teaching. If not, why?

After we collected information through the above sources of data, the degree of teacher support for the vision in the National Science Education Standards was determined and provided the basis for dividing the teachers into three groups: Group 1 had teachers who are strongly supportive, Group 2 consisted of teachers who were neutral, and Group 3 included those who weakly supported the visions provided by the NSES. Group 1 and Group 3 were selected for analysis in order to maximize the purpose of the study about how teacher's support influences on students' learning. In Module I, eight teachers (N=8) were found supportive and six teachers (N=6) ended up being weakly supportive. On the other hand, Module II had six teachers (N=6) as supportive and four teachers (N=4) weakly supportive. The decision for determination of each group was based on the judgment of three experts in science education who analysed and interpreted the gathered data from the above two sources. When the three experts were in conflict about determination, they discussed with each other and sometimes with the project manager until 90 percent agreement was reached. After grouping by three experts, differences were compared and discussed. The panel of three experts finally decided with additionally obtained information of the teacher's teaching practices that mostly came from the field testing feedback in addition to the project manager's comments.

Analysis of the Data

Twenty-four teachers reported results with the EarthComm Field Testing Instruments in terms of student achievement scores for Module I while 16 teachers reported them for Module II. Data gathered for Module I were obtained from teachers who have 2-33 years of teaching experiences mostly in urban and rural setting. The students who participated in the pretest did not match the students in posttest for Module I because some students who missed the pre test showed up in the post test and vice versa. However, the students for Module II were matched. Thus, the means of student scores for Module I were used to conduct a statistical analysis rather than using raw scores. This step made it possible to accomplish two-way ANOVA for Repeated Measures concerning the impact of teacher thinking on student achievement scores. Yet the power of the test was weakened by using means rather than raw scores for each student (Hinkle, Wiersma, and Jurs, 1988).

RESULTS

Teacher Thinking and Student Achievement Scores

Teacher Thinking

Thirty-one individual teachers enrolled in the program to field test Modules I and II. The participants were divided into two groups thereby allowing the researcher to compare results of their students' learning among those who strongly support, and weakly espouse the visions in the NSES. The variance of analysis was conducted for determining significant changes in student achievement with the implementation of EarthComm during the field test.

Module I

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. We aggregated the scores in each group and computed two-way ANOVA for Repeated Measures. These results are presented in Table 1. Analyses showed statistically significant gains at $p < .05$. The effect sizes for these gains were stronger for highly supportive group than weakly supportive group. 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 scores ranged from 9.25 to 17.05. Particularly, student achievement scores for T2 (9.49 for pretest means and

15.00 for the posttest), T4 (10.76 for the pretest means and 17.04 for the posttest), and T6 (9.57 for the pretest means and 17.05 for the posttest) are noted because there was a big jump in their scores. 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 lessons.

Table 1 Students' pre- and posttests gains for Two Groups of Teachers Who Strongly Support and Weakly Support the NSES Teaching Standards for Module I

Group	Teacher	N	Pretest Mean (SD)	N	Posttest Mean (SD)	Effect Size
Strongly Supportive Group (N=8)	T2	87	9.49 (2.78)	95	15.00 (1.97)	2.23*
	T3	35	11.54 (2.76)	33	14.00 (2.22)	0.98*
	T4	95	10.76 (2.74)	94	17.04 (3.04)	2.17*
	T6	21	9.57 (3.08)	21	17.05 (2.97)	2.47*
	T7	10	8.10 (3.56)	11	11.09 (2.27)	1.01*
	T14	15	10.07 (3.75)	17	13.53 (2.68)	0.66*
	T20	12	6.00 (1.87)	12	9.25 (4.44)	0.95*
	T21	29	8.90 (3.02)	21	12.86 (2.73)	1.36*
Weakly Supportive Group (N=6)	T1	39	9.14 (2.71)	37	11.06 (3.43)	0.62*
	T10	76	7.86 (2.44)	70	9.46 (3.46)	0.54*
	T15	86	8.52 (3.09)	79	9.72 (2.98)	0.40*
	T16	24	8.58 (4.05)	24	10.71 (4.45)	0.50*
	T23	24	6.83 (2.87)	21	8.00 (3.10)	0.39*
	T24	28	7.82 (2.16)	27	8.37 (2.64)	0.09*

* $p < .05$.

In testing for the effect of strongly and weakly support of teachers with the standards of teaching, assessment, content, and professional development in the NSES, the difference between the strongly and weakly supportive groups is significant ($F=8.36$, $p < 0.05$). 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 when taught by teachers who strongly agree with the teaching envisioned by the developers and the NSES. The mean of all student scores for the group of teachers who weakly espoused agreement with the Standards included in the NSES was 8.13 (SD=0.80) for the pretests and 9.55 (SD=1.22) for the posttests, which was statistically significant. However, this change in average was not as dramatic as the changes for the supportive group. This result indicated that student achievement was also statistically significant when taught by teachers who were weakly supportive of the NSES. However, the change from pretest to posttest for the teachers who were strongly supportive of the NSES was greater than for teachers who were weakly supportive of the NSES.

Module II

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. Two-way ANOVA for Repeated Measures was used to determine whether the means of the posttests were statistically different than those of the pretests. Table 2 reports the mean scores of students' pre- and posttests. All the analyses showed statistically meaningful gains at $p < .05$. Overall, highly supportive group showed stronger effect sizes for these gains than weakly supportive group in Module II. 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 (Note: T2 and T6 teachers are the ones whose students scored particularly higher than those in other teachers in Module I, too). 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.

In testing for the effect of the groups that were deemed highly aligned and weakly aligned with the visions described in the NSES, the difference between the two groups of teachers is significant ($F=64.00$, $p < 0.05$). The mean of all students 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 scores actually decreased after the implementation of EarthComm. This result indicates that student achievement was not significantly increased 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 when taught by teachers who strongly agree with the teaching envisioned by the NSES.

Table 2 Students' pre- and posttests gains for Two Groups of Teachers Who Strongly Support and Weakly Support the NSES Teaching Standards for Module II

Group	Teacher	N	Pretest Mean (SD)	N	Posttest Mean (SD)	Effect Size
Strongly Supportive Group (N=6)	T2	86	7.31 (2.77)	86	17.70 (3.48)	3.30*
	T3	34	10.09 (2.67)	34	11.47 (3.28)	0.46*
	T4	64	6.39 (2.52)	64	7.04 (3.14)	0.23*
	T6	13	6.31 (2.53)	13	16.54 (3.84)	3.15*
	T7	18	5.39 (2.25)	18	7.39 (3.58)	0.67*
	T29	33	5.30 (1.86)	33	5.76 (1.75)	0.25*
Weakly Supportive Group (N=4)	T1	9	7.89 (2.71)	9	6.00 (2.60)	-0.71*
	T28	18	6.39 (2.52)	18	7.11 (3.14)	0.25*
	T30	22	6.59 (1.87)	22	8.86 (2.98)	0.91*
	T31	11	5.55 (2.16)	11	7.73 (2.28)	0.98*

* $p < .05$.

Discussion and Conclusions

EarthComm student scores increased when taught by teachers whose views of science teaching and learning were consistent with those outlined in the NSES, while student scores were not significantly increased by teachers who were weakly supportive to the NSES visions. This outcome was seen in the field-testing of EarthComm Modules I and II (see Tables 1 and 2). This means that EarthComm curriculum has the desired effect on student learning when taught by teachers who espouse reform-minded principles in high school earth science. In other words, the improvement of student learning occurred especially when the field-test teachers for EarthComm agreed philosophically with the National Science Education Standards. The interpretation of this result is based on the assertion that teacher thinking or belief impacts not only teaching behaviors but also student achievement. Welch (1979)'s meta-analysis of 90 studies that examined the effects of the new curricula indicated a positive impact on student learning and improved classroom instruction. In addition, Shymansky, et al. (1983) concluded in their meta-analysis of data from 105 studies on the effects of pre-1955 science curricula compared with post-1955 curricula that the new curricula had a positive effect on student achievement, attitudes, laboratory skills, critical thinking, problem solving, creativity, and logical reasoning. The newer science curricula were characterized by inquiry approach in teaching and learning. The newly developed curricula were getting recognition from the public. Welch (1979) found that between 30% and 39% of elementary and junior high schools and 60% of the grade 10-12 schools used one of more of the federally funded courses. However, there are arguments for teacher role in curriculum development and implementation to change to something more than just acceptors. The teacher plays a complex role in determining the form of the curriculum that is actually experienced by the students. Therefore, teachers are called for the training of the "curriculum proof" teachers (Zoller and Watson, 1974).

The EarthComm teachers were all trained with a five-day workshop about what and how to teach earth science before they taught an EarthComm module in their classrooms. 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, Czerniak, and Lumpe, 1996; Crawley and Koballa, 1992). Understanding of the belief structures of teachers has been found to be important for improving teaching (Pajares, 1992).

The EarthComm curriculum resulted in improvement in student learning when taught by teachers who were highly supportive of the visions espoused in the National Science Education Standards. In other words, their teaching was inquiry-based and focused on hands-on activities that investigated questions by using multiple process skills. These activities facilitated students in performing investigations that established their own scientific explanations with evidence and that could then be communicated with other students. Students in their particular classes were encouraged to investigate further, if needed, to develop understandings of the science content. However, student scores in EarthComm classes were not significantly increased by teachers who weakly supported the NSES visions. Therefore, teacher thinking had a primary impact on student achievement significantly in the EarthComm classes. These findings of EarthComm clearly provide a niche for earth science education at the high school level, especially when it is taught in ways that coincide with the NSES visions. These findings also offer an opportunity for curriculum developers and teachers to consider the issues and implications found in the study when they select and utilize the curriculum. The results of the study point to the fact that teachers need to be informed through teacher professional development program and support the visions elaborated in the NSES in order for EarthComm to be successful. Use of EarthComm results in improved student understanding about the Earth. However, EarthComm may not help in developing the same degree of student understanding about the Earth systems unless the teachers understand and agree with the visions recommended in the National Science Education Standards and use the materials as designed.

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