The purpose of this study was to compare the 
effects of inquiry-based teaching and traditional 
teaching on student learning of earth-science con-
cepts at the secondary-school level. A quasi-
experimental non-equivalent control-group design 
was employed to identify any significant gains in 
student achievement. Students chosen to partici-
pate in the study included 232 earth-science students 
(9th grade) enrolled in six earth-science classes. 
The experimental group received two weeks of 
the inquiry-based instruction, whereas the control 
group received the traditional lecture-type instruc-
tion. Selected items from the Taiwan Indicators of 
Educational Progress in Science Process Skills 
and Taiwan Entrance Examinations for Senior High 
School were used to measure student learning of 
earth-science concepts. The data were analyzed with 
an analysis of covariance (ANCOVA) on posttest 
scores with pretest as the covariate. The results indi-
cated that students taught using inquiry-based in-
structional method scored significantly higher on 
the selected test items than those taught by a 
traditional teaching approach (F=6.75, p<.05). Most 
notably, there was significant improvement in achieve-
ment test performance, especially on the compre-
hensive (F =3.94, p<.05) and integrated (F=6.47, 
p.<.05) test items but not on the “factual knowl-
edge” (F = 3.43, p>0.05) test items.

Keywords: Education – geoscience; education – secondary; education – outside United States.

Introduction

Inquiry-based teaching approaches have long been 
employed and prevailed in the main-stream classroom 
since the NSF curriculum-reform efforts in the late 
1950s and early 1960s. Shymansky, Kyle, and Alport 
(1983) presented a meta-analysis of the effects of these 
inquiry-associated curricula on student performance 
and found that the new science curricula enhanced 
student science achievement and process skills, as well 
as attitudes toward science. The strongest reported 
effects were for biology; weakest were for earth sci-
ence. Research on inquiry-based teaching practices in 
typical middle- or high-school classrooms have shown 
some positive effects on student achievement (Chang 
and Barufaldi, 1997; Chiappetta and Russell, 1982; 
Ertepinar and Geban, 1996; Gabel, Rubba, and Franz, 
1977; Geban, Askar, and Ozkan, 1992; Hall and 
McCurdy, 1990; Henkel, 1968; Muloop and Fowler, 
1987; Richardson and Renner, 1970; Russell and 
Chiappetta, 1981; Saunders and Shepardson, 1987) 
and on laboratory skills or science-process skills (Basaga, 
Geban, and Tekkaya, 1994; Mattheis and Nakayama, 
1988; Tobin and Capie, 1982). Most of the aforemen-
tioned research studies on inquiry-based teaching 
strategies have emphasized life science, physics, and 
chemistry; only a few studies have focused on earth 
science. Therefore, it is important to explore whether 
an inquiry-based instructional method will have 
similar effects on students’ learning of earth-science 
concepts at the secondary-school level.

Inquiry-based instruction in the literature has been 
closely associated with other teaching methods such
as problem-solving, laboratory instruction, cooperative learning, and discovery instruction. These methods are commonly referred to as the inquiry approach, which often emphasizes extensive use of science-process skills and independent thought. The inquiry-based instructional method developed and employed in the current study specifically emphasized gathering and interpreting data by secondary-school students in a cooperative-learning setting with the goal of improving student learning of earth-science content.

Recent science-education standards in the US propose that all students should both learn about scientific inquiry and learn science through inquiry (National Research Council, 1996). Many researchers in the area of earth-science education have attempted to develop or employ inquiry-based instructional methods at the college level. For example, Stefanich (1979) implemented an inquiry-based teaching method which encourages students to gather data in order to interpret geological events. McKenzie and Fuller (1987) adopted a modified guided-design instructional option for non-science majors in the introductory geology course at Ohio State University – The Group Approach to Solving Problems (GRASP) – which focused on problem solving and group dynamics. The GRASP format used fewer lectures but many laboratory exercises based on problem-solving sessions. The results indicated that the GRASP approach interested students in active learning and provided students the opportunity for group cooperation. Starr (1995) also examined the effects of cooperative-learning strategies on geology achievement and student attitude toward science in a Washington State University physical-science course. The results indicated there was an improvement in both achievement and student attitude toward science.

While some previous research has shown that an inquiry-based instructional method can improve student science-process skills, concept learning, and achievement, research on explicit teaching (that is, traditional instruction) has also revealed that student achievement is improved for certain kinds of students and for selected kinds of instructional objectives (Waxman, 1991). After reviewing research on inquiry-based teaching, Plick (1995) stated that “Research on inquiry-based instruction has produced mixed results with the clearest effects occurring with more capable students, who have well trained teachers, and a supportive classroom environment” (p. 17). Accordingly, it is interesting and necessary to make a comparison between the inquiry-based instruction and the traditional teaching method in terms of their effects on student learning of earth-science concepts in typical classroom settings regardless of student capability.

**Purpose**

The purpose of this study was to compare the effects of inquiry-based teaching and traditional teaching on students learning of earth-science concepts at the secondary-school level.

**Methodology**

Subjects: Two hundred thirty-two ninth-grade earth-science students and one earth-science teacher participated in this study. The students were enrolled in six earth-science classes at a modern public junior-high school located in the northern region of Taiwan. Random assignment of students to new classes is not possible in the educational system in secondary schools in Taiwan; intact class set is the unit of the experimental design. Three intact classes (n=116) were randomly assigned to the inquiry-based instruction group; the other three classes (n=116) were randomly assigned to the traditional-lecture group. The students are typical secondary-school students at 15 years of age; gender was equally distributed among the classes.

**Treatment:** It is important to distinguish between “inquiry” and “traditional” instruction for this study. Welch, Klopfer, Aikenhead, and Robinson (1981) defined inquiry-based teaching as emphasizing observation and interpretation of data. Inquiry-based instruction in this current study similarly emphasizes hands-on, minds-on activities that involve gathering data and information. In addition, students also critically examine data for relationships and interpret the data. Another key feature of the inquiry-based teaching is cooperative learning, including small-group discussions. Small-group discussion is intended to increase interaction among students and with the instructional materials. During group discussion, students clarify their own ideas and communicate with each other. The inquiry-based instruction in the study is designed to engage students in practicing science-process skills, such as observing, measuring, and interpreting data, seeking solutions to problems, and, in due course, improving their higher-order thinking skills.

The inquiry-based instruction and instructional units employed in this study focused on the topic “The apparent motion of the sun in the sky.” The treatment consisted of a two-week period of earth-science instruction, emphasizing inquiry. Student engagement was encouraged by having students gather information and interpret data generated from hands-on activities and group discussion. During one hands-on activity, for example, students were first provided a diagram showing a series of stick shadows under the sun on March 21 or 22 (spring equinox) in Taiwan. Students were then asked to project (or plot) different locations of the sun on a small transparent celestial sphere for that specific day. After observing the various locations of the sun in a day, students were required to interpret data and make explanations through group discussion. This activity was also repeated for June 21 or 22 (summer solstice), September 22 or 23 (autumnal equinox), and December 21 or 22 (winter solstice) for further comparison and interpretation purpose. Class presentation of group-discussion results and teacher’s discussions with students were followed by the teacher’s explanation of the earth-sun system. The most important characteristic of the lessons is the “student-centered” activities that are designed to encourage students to become more adept in using science-process skills and more knowledgeable about earth-science concepts.

The traditional instructional method used in this study stressed a teacher’s lectures and explanations...
Instrument: The Achievement of Concept Learning Test: Student achievement was measured by using selected items from the Taiwan Indicators of Educational Progress in Science Process Skills (TIEPSPS) and the Taiwan Entrance Examination for Senior High School (TEESHS) – Earth science subject. These tests are the most widely used achievement-related and science-process skills tests in Taiwan. Twenty-seven test items were used as both pretest and posttest measures of student achievement.

The content validity of the instrument was verified by a panel of experts including four professors from the Department of Earth Science, National Taiwan Normal University, and six secondary-school earth-science teachers. These experts checked the degree of correspondence between the textbook content and test items and determined that the nature of the test items did correspond to the important concepts introduced in the textbook. The Cronbach alpha method was used to determine the reliability coefficient of both the pretest and posttest. The reliability coefficient was 0.61 for the pretest and 0.83 for the posttest.

Individual items in the instrument were further classified into three categories (factual, comprehensive, and integrated) corresponding to Bloom’s Taxonomy (1956) of knowledge (factual), comprehension, and application (integrated) levels. Factual items emphasize recognition or recall of ideas; comprehension items focus on the understanding of ideas or concepts; integrated items require students to apply solutions to an appropriate situation. The same panel of experts, who were knowledgeable about the criteria of these categories, independently classified the items into the categories with high percentage agreement (88.9%), and few disagreements were resolved by discussions between the experts after completing the categorizing procedure. Consequently, the instrument included seven items at the factual level, thirteen items at the comprehensive level, and seven items at the integrated level. The classification of test items aims at investigating students’ levels of understanding and achievement of earth-science concepts.

The following three questions are respective examples of the sublevel test items used in the test. (Note: Correct answers are designated by *)

1. Factual-level item: Figure 1 represents the angle between the sun and the ground. If you face southward, A is located at about 45 degrees, B is at 66.5 degrees, Band C is right at the zenith. Incidentally, when you are facing northward, D is also at about 66.5 degrees. Which one of the following letters might represent the location of the sun at its zenith on December 21 or 22 (winter solstice) in Taiwan? (1) A* (2) B (3) C (4) D.

2. Comprehensive-level item: Which one of the lines in Figure 2 might represent the correct stick shadow under the sun at 3:00 pm on September 22 (autumnal equinox) in Taipei? (1) OA* (2) OB (3) OC (4) OD.

3. Integrated-level item: Figure 3 represents the angle between the sun and the ground one day at a city (23.5°) in Taiwan. Figure 4 shows the revolution of the earth around the sun. Which one of the following letters might represent the location of the earth in Figure 4 when the sun is at its zenith (90°) in Figure 3? (1) A* (2) B (3) C (4) D.

Results

The descriptive statistics on pretest scores with three levels of understanding are summarized in Table 1; the descriptive statistics and ANCOVA analysis on posttest scores are summarized in Table 2. The results indicated that the inquiry-based instructional method did significantly improve student learning of earth-science concepts compared to the traditional teaching method (F = 6.75, p<0.05) as shown in Table 2 (total items), especially at the comprehensive (F = 3.94, p<0.05) and integrated levels (F = 6.47, p<0.05). However, there were no significant gains in student achievement at the factual level among the experimental groups when compared to the control groups as shown in Table 2 (factual level: F = 3.43, p >0.05).

Discussion

The present study, consistent with previous studies, shows that inquiry-based instruction produced positive outcomes on student concept learning, especially at higher cognitive levels of Bloom’s Taxonomy (Chang and Barufaldi, 1997; Chiappetta and Russell, 1982; Ertepinar and Geban, 1996; Gabel, Rubba, and Franz, 1977; Geban, Askar, and Ozkan, 1992; Henkel, 1968; Mulyo and Fowler, 1987; Saunders and Shepardson, 1987). It may be that pupils exposed to the treatment had the opportunity to observe, record, and interpret
data on their own during hands-on investigative activities. Accordingly, the science-process skills emphasized in this study might help the experimental group attain greater understanding of earth-science concepts than those students in the control group.

It is also suggested that inquiry-based teaching does not appear to improve student's retention of factual knowledge but does improve higher-level understanding of concepts among the subjects. Students taught by the inquiry-based instructional method may not outperform at the factual level those taught by the more traditional approach because rote memorization may favor student performance at that level. It is interesting to note that inquiry-group students did perform significantly better on achievement for the upper-level items (comprehensive and integrated levels) than traditional-group students, which apparently resulted from emphasis of the instruction on science-process skills and higher-order skills of students. This differential effect merits further exploration.

According to the 1996 National Science Education Standards in the US (NRC, 1996), “teaching science as inquiry provides teachers with the opportunity to develop student abilities and to enrich student understanding of science” (p. 121). The inquiry teaching proposed in the present study emphasizes inquiry, interpretation of data, group discussions, and cooperative learning; these strategies might help develop students’ higher-order skills and facilitate learning of earth-science concepts. It is suggested that students could learn science through the inquiry approach. The data also suggest that effective instruction in earth science, such as the inquiry-based instruction, should emphasize “student-centered activities” and de-emphasize “teacher-centered lectures” in teaching earth-science concepts.

### Table 1. Summary of descriptive statistics on students' pretest scores.

<table>
<thead>
<tr>
<th>Level</th>
<th>Inquiry Groups Mean (SD)</th>
<th>Traditional Groups Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factual Level</td>
<td>4.0(2.0)</td>
<td>3.7(1.9)</td>
</tr>
<tr>
<td>Comprehensive Level</td>
<td>3.5(2.0)</td>
<td>3.5(2.0)</td>
</tr>
<tr>
<td>Integrated Level</td>
<td>1.6(1.1)</td>
<td>1.6(1.0)</td>
</tr>
<tr>
<td>Total Items</td>
<td>9.1(3.8)</td>
<td>8.8(3.3)</td>
</tr>
</tbody>
</table>

### Table 2. Summary of descriptive statistics and analysis of covariance on students' posttest scores.

<table>
<thead>
<tr>
<th>Level</th>
<th>Inquiry Groups Adjusted Mean (SD)</th>
<th>Traditional Groups Adjusted Mean (SD)</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factual Level</td>
<td>5.6(1.7)</td>
<td>5.2(1.9)</td>
<td>3.43</td>
</tr>
<tr>
<td>Comprehensive Level</td>
<td>6.0(3.1)</td>
<td>5.4(2.9)</td>
<td>3.94*</td>
</tr>
<tr>
<td>Integrated Level</td>
<td>3.1(1.7)</td>
<td>2.6(1.5)</td>
<td>6.47*</td>
</tr>
<tr>
<td>Total Items</td>
<td>14.6(4.3)</td>
<td>13.2(5.4)</td>
<td>6.75*</td>
</tr>
</tbody>
</table>

* p < 0.05
Inquiry Teaching and Its Effects on Secondary School Students’ Learning of Earth Science Concepts

Handson and minds-on activities during inquiry-based instruction appeared to have helped students’ learning of earth-science concepts since these activities provided students with first-hand experience in doing science and the opportunities to collect and interpret data and to draw conclusions. Results of this study support the notion that teachers need to encourage students to develop their inquiry skills as early as possible.

References Cited
Mattheis, F.E., and Nakayama, G., 1988, Effects of a laboratory-centered inquiry program on laboratory skills, science process skills, and understanding in middle grades students: ERIC Document Reproduction Service No. ED307148.

Food for Thought
All times seem special to those who live in them. But it is neither parochial pride nor shortsighted despair to say that our time is more special than others. According to the fossil record, only five times in the past six hundred million years has there been such abrupt havoc in the biosphere. Only five times have so many twigs and branches been lopped from the tree of life at once. . . .

Never before was such havoc caused by the expansion of a single species. Never before was the leading actor aware of the action, concerned about the consequences, conscious of guilt. For better and for worse, this may be one of the most dramatic movements to observe evolution in action since evolution began.

Inquiry Teaching and Its Effects on Secondary School Students’ Learning of Earth Science Concepts

Food for Thought

The principle that children should enter a new grade already sharing the background knowledge required to understand the teacher and each other is at bottom the principle that enables the functioning of an entire community or nation. People cannot effectively meet in the classroom or in the marketplace unless they can communicate with and learn from each other. It is the duty of a nation’s educational system to create this domain of public communicability. It cannot do so without the common school, and the common school cannot be truly such without providing each child the shared intellectual capital that will be needed in each early grade, and needed ultimately in society after graduation. A shared public culture that enables public communicability is essential to an effective community at every age and stage of life, and most emphatically in the early grades, when deficits can be made up. Once out of to communicate and learn.