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ABSTRACT

The purpose of this study was to investigate and describe selected instructional strategies (traditional and constructivist) and grouping practices (homogeneous and heterogeneous) on conceptual understanding and critical thinking skills in biology classrooms in three high schools. The context of the study was the teaching and learning of plant nutrition in the secondary biology classroom. Conceptual understanding was assessed through a two-tiered multiple choice test developed by Haslam and Treagust (1987). The test was used as a pretest and a posttest. The plant nutrition portion of The Critical Thinking in Biology Test was used to assess the critical thinking skills of the students. Classroom observational data was compiled using the Science Classroom Rubric (Burry, Sunal, Turner, and Pittman, 1993). Analysis of covariance and paired T-test results indicated that the grouping climate alone had a significant effect on conceptual change. The classes that were grouped heterogeneously scored significantly higher on the conceptual change test than those classes that were grouped homogeneously. No significant effects were found for critical thinking. Contains 63 references. (Author/MKR)

The Effects of Grouping and Instructional Strategies on Conceptual Understanding and Critical Thinking Skills in the Secondary Biology Classroom

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Abstract

The purpose of this study was to investigate and describe selected instructional strategies and grouping practices on conceptual understanding and critical thinking skills in the secondary biology classroom. The context of the study was the teaching and learning of plant nutrition in the secondary biology classroom. Conceptual understanding was assessed through a two-tired multiple choice test developed by Haslam and Treagust (1987). The test was used as a pre-test and a posttest. The plant nutrition portion of The Critical Thinking in Biology Test was used to assess the critical thinking skills of the students. Classroom observational data was compiled using the Science Classroom Rubric (Burry, Sunal, Turner, and Pittman, 1993). Analysis of covariance and paired T-test results indicated that the grouping climate alone had a significant effect on conceptual change. The classes that were grouped heterogeneously scored significantly higher on the conceptual change test that those classes that were grouped homogeneously. No significant effects were found for critical thinking.

Introduction and Theoretical Background

This study investigated and described selected instructional strategies and grouping practices and their separate and combined effects on conceptual understanding and critical thinking skills in the secondary biology classroom. Two instructional strategies, one to be referred to as traditional and the other to be designated as constructivist were chosen for the focus of this inquiry. The two instructional strategies used in this study are based on two different philosophical views of learning. Behavioral psychology, that views learning as a permanent, observable change in behavior, serves as the foundation for traditional instruction. Constructivist instruction is based on cognitive psychology that perceives learning as an adaptive and active process that involves changes in the content and organizational structure of the mind (Champagne & Klopfer, 1984).

The following descriptions of the two classroom approaches is based on a comparison of a traditional classroom versus a constructivist classroom compiled by Brooks and Brooks, 1993 (p.17). The traditional science classroom instruction is characterized by a fixed, fact based curriculum, didactic teaching, teacher centered instruction, individual student work, and pen and paper assessment. The teacher organizes and presents the science content in a way that allows the students to learn the material mimetically. The constructivist science classroom is characterized by a flexible, concept based curriculum, student centered learning, hands-on activities, group work, and ongoing, alternative assessment through student exhibitions. The teacher organizes and implements activities that allow students to develop an understanding of science concepts. In this study the terms conceptual change strategies, constructivist approach, constructivist teaching strategies, and constructivist teaching sequence will refer to classroom practices that are based on the constructivist theory of learning and contribute to the development of a constructivist science classroom.

Grouping practices describe the academic makeup of a classroom. Homogeneous or like ability grouping includes any deliberate attempt to group students by academic ability or intelligence measure (i.e. I.Q., science scores, math scores). Heterogeneous or mixed ability grouping places students in the same classroom regardless of perceived academic ability. Heterogeneous grouping, the grouping of students of mixed abilities, is a vehicle for providing students with a common education. This differs from the homogeneous grouping, or grouping students of similar abilities, which is the prevalent and often preferred grouping organizational structure in secondary education in the United States. Homogenous grouping is also known as "tracking" or "leveling".

Achievement in science has been defined and assessed in numerous ways. Most studies reviewed measure achievement by using fact-based paper and pencil tests. In this study student achievement will be defined as conceptual understanding, the ability of students to discard naive conceptions and to explain correctly biological concepts of plant nutrition. Additionally, the ability to think critically will be defined as the skill to precisely, persistently, and objectively analyze any claim source, or belief in order to judge its accuracy, validity and worth (Beyer, 1988).

<u>Instructional Strategies</u>

The research on instructional strategies in the science classroom neglects to take into account the possible effect grouping may have on the climate of the classroom (Boulanger, 1981; Froit, 1976; Kenner & Raghubin,1979; Johnson, Johnson, Holubek, & Roy, 1984; Oakes, 1985; Purser & Renner, 1983;

Schneider & Renner, 1980; Slavin, 1981; Wise & Okey, 1983). Conversely, the majority of studies on grouping neglect to include the impact of particular instructional strategy information in their analyses (Gamoran & Berends, 1987; Gamoran, 1987; Hoffer, 1992 ; Kerchoff, 1986; Kulik & Kulik, 1982; Slavin, 1990). Three studies, Hacker and Rowe (1993), Hand and Treagust (1991), and Plewes (1979), are exceptions to the last statement. Hacker and Rowe (1993) and Plewes (1979) investigated grouping practices and whole class versus individualized instruction in the science classroom. In these studies homogeneously grouped students were taught in a whole class manner, whereas heterogeneously grouped students were taught by individualized methods. Plewes (1979) indicated that mixed ability grouping results in a deterioration of academic performance. Hacker and Rowe (1993) noted a decrease in student interactions in the heterogeneously grouped science classroom when compared to the homogeneousy grouped classroom. Hand and Treagust (1991) reported on research using a constructivist teaching strategy versus a traditional teaching strategy in a secondary science classroom of low achievers. The study indicated that a constructivist teaching strategy improves process skills, such as problem solving, in a homogeneous secondary science classroom.

Research has indicated that particular instructional strategies can affect science achievement. A study by Kenner and Raghubin (1979) and a meta-analysis by Wise and Okey (1983) found that programs with hands-on inquiry improved achievement. Froit (1976) found that science programs that emphasized inquiry and experimentation could promote the development of formal operational thought in ninth graders. Boulanger (1981) found that the concrete teaching strategies, preinstructional strategies, and a combined inductive nondirect teaching approach were associated with improved cognitive achievement in the secondary science classroom. Studies by Johnson, Johnson, Holubek and Roy (1984), Oakes (1985), and Slavin (1981) demonstrate that cooperative learning promotes student achievement across all ages, all grade levels, all subjects, and all tasks. Cooperative learning has also been found to promote critical thinking and higher reasoning strategies (Johnson, Johnson, Holubek, & Roy, 1984; Oakes, 1985). Conceptual change strategies, such as curricula based on constructivist theory, can improve student understanding in science (Hand & Treagust,1991; Hewson & Hewson, 1983; Purser & Renner, 1983; Schneider & Renner, 1980 ; Smith, Blakeslee, & Anderson, 1993). Of the above mentioned strategies, conceptual change, through the agency of constructivist teaching sequences, provides the most comprehensive approach to science instruction. A constructivist lesson is presented from whole to part, relies on student questions, interactions and discussions to guide curriculum activities, encourages group learning, includes experiential activities, and integrates assessment with the teaching and learning process (Brooks & Brooks, 1993). Imbedded in the constructivist teaching strategy are instructional strategies that are likely to promote student achievement and critical thinking in science.

Grouping Practices

As noted by Lynch (1994), there is a paucity of research on ability grouping in secondary science classes. Therefore, one must look to the "general " research on grouping, and deduce conclusions based on the assumption that the results are not subject specific and can be generalized to grouping in science classes.

The research literature concerning heterogeneous and homogeneous grouping practices seems inconsistent. Survey research findings are mixed according to Gamoran and Berends (1987). They concluded that survey research indicates that tracking may be a factor in affecting student achievement, post-secondary plans, and attitudes about school. Survey research studies by Alexander, Cook, and McDill (1978), Gamoran (1987), Hoffer (1992), and Kerchoff (1986) indicated that ability grouping favors high ability students and has no effect on middle or low level students. Slavin's (1990) synthesis of ability grouping research and Tingle and Good's (1990) study of chemistry students showed no difference in achievement between heterogeneously grouped or homogeneously grouped students. Kulik and Kulik's (1982) meta-analysis of ability grouping studies indicated that ability grouping favors high ability students and has no effect on middle or low level students. Plewes (1979) concluded that science achievement improves when students are grouped for instruction by ability. Therefore, the quantitative research on grouping is mixed.

Qualitative research paints a different picture. Oakes (1986) noted that students in a heterogeneously grouped classroom did as well as or better than their peers in a tracked classroom. Teacher Education Resources (1988) reported that there is no evidence that placement in a heterogeneous classroom inhibits achievement of the higher ability students. Oakes (1985) and Gamoran and Berends (1987) indicated that there are differences in classroom climate, teacher expectations, teacher strategies, and student attitudes between the low tracked classes and high tracked classes. According to Oakes (1985) and Gamoran and Berends (1987) the low tracked classrooms promote a negative classroom climate characterized by anti-school behavior, defeatist attitudes, alienation on the part of the students, and lower expectations, and less innovations on the part of the teacher.

The discrepancies between the quantitative and qualitative research studies may be attributed to differences in the research methodologies and purposes. In the quantitative research studies standardized test and surveys were used to determine the relationship between student outcomes and grouping practices. In the qualitative research, particularly Oakes (1985), standardized test results, surveys and detailed observational descriptions of the secondary classroom were used to present a picture that included teacher expectations, classroom climate and instructional strategies. The qualitative research was trying to describe the conditions that account for the effects of grouping and student achievement. As Gamoran and Berends (1987) noted, the ethnographic evidence does not demonstrate that tracking creates differences in student attitudes and achievement but it does indicate an association between tracking and instructional strategies. It is apparent that there is a need to include observational data of instructional practices in the assessment of grouping. Hacker and Rowe's (1993) study attempted to respond to this need yet concluded that a change from homogeneous to heterogeneous grouping was not accompanied by prescribed pedagogical changes. They suggest that future research include "the relative efficacies of various combinations of ability groupings and instructional strategies." (p. 230).

Traditionally, the science classroom has been assumed to be unique from other discipline areas. Since the early sixties, the NSTA has recommended that science education include laboratory investigations (NSTA 1962, 1971, 1990). Usually, the laboratory exercises are conducted in lab groups of two to five members. Therefore, students and teachers in science classrooms should be involved in hands-on, student-centered, interactive activities. Also, they should be accustomed to working in groups on a common problem.

Unfortunately, this view of the science classroom may be inaccurate. Wise and Okey (1983) reported that the typical science classroom is fact based, with instruction presented verbally and with few opportunities to manipulate materials or engage in activities. According to Goodlad (1984) the science classroom did not differ from the other disciplines' classrooms, which were characterized by teacher centered, lecture/demonstration activities. In the introduction of The Content Core (NSTA, 1992), the authors describe The United States science program as being preoccuppied with facts and textbook driven. This picture of the science classroom coupled with the decreasing achievement of United States students in science, and the decreasing enrollment in secondary science classes has led professional science organizations to seek reform in the goals of science education, and in the teaching and learning of science.

Science educators are calling for science education that produces a scientifically literate populace who are capable of thinking critically, as well as an adequate number of scientists and engineers (American Association for the Advancement of Science (AAAS),1989; National Science Teachers Association (NSTA),1990,1992; Zeidler, Lederman, & Taylor, 1992; Zeidler & Duffy, 1994; Zeidler, 1995). In order to meet these goals AAAS (1989) and NSTA (1990, 1992) recommend heterogeneous grouping in the science classroom and a constructivist approach to learning science.

Instructional strategies such as cooperative learning, experiential learning, pre-instructional methods and conceptual change strategies appeared to promote achievement, concept attaiment, and critical thinking skills (Boulanger, 1981; Collea & Nummedal, 1979; Hand & Treagust, 1991; Harty & Nasser,1983; Johnson & Johnson, 1979; Johnson, Johnson, Holubek, & Roy, 1984; Kenner & Raghubin, 1979; Purser & Renner, 1983; Ramsey & Howe, 1969; Schneider & Renner,1980; Smith, Blakeslee, & Anderson, 1993; Slavin, 1981; Tobin, Capie, & Bettencourt, 1988; Tomlinson-Keasey & Eisert, 1977). Studies on classroom grouping practices indicated an association between achievement, critical thinking, and conceptual understanding and the grouping climate (Alexander, Cook, & McDill,1978; Gamoran, 1987; Gamoran & Berends, 1987; Hoffer, 1992; Kerchoff, 1987; Kulik & Kulik, 1982; Oakes, 1985; Slavin, 1990).

Each of the above mentioned research agendas provides science educators with partial information that may help improve student understanding and thinking skills. While the grouping literature lacks information about instructional strategies, the instructional strategy literature neglects to include information on the grouping climate of the classroom. The image of the science classroom as interactive and student centered seems inaccurate. Consequently, this study by combining instructional strategies and grouping climates in the science classroom, attempted to provide a more robust view of contemporary science classrooms.

Design and Methodology

The purpose of this study was to examine the impact of two instructional strategies (traditional and constructivist) and two grouping practices (heterogeneous and homogeneous) on academic achievement and critical thinking in the biology classroom. The experiment included the teaching of a unit on plant nutrition. Research has indicated that students have problems understanding plant nutrition concepts and harbor naive conceptions concerning plant nutrition. (Bell, 1985; Bell & Brook, 1984; Haslam & Treagust, 1987; Oldham, Driver, & Holding, 1991; Roth, Smith & Anderson, 1983; Simpson & Arnold, 1982a; Simpson & Arnold 1982b; Stavy, Eisen & Yaakobi, 1987; Waheed & Lucas, 1992). Eight classrooms with four teachers were used in the study. A conceptual model based on White and Tisher (1985) directed the design of the experiment (see figure 1). White and Tisher (1985) offered a model for research in science education that involves the relationships among external influences, attributes of the learner, and student performance. In this study, the effects of the three external aspects; **context**, as in classroom grouping practices, **past learner experiences**, measured by the conceptual change pre-test; and **instruction**, defined as traditional versus constructivist teaching were included. **Student performance** was assessed by a biology conceptual understanding test and a critical thinking test.

Eight major reseach questions were addressed in the study. The context for each research question was the secondary biology classroom. They are categorized according to grouping climate, instructional strategy, and combined effects of grouping climate and instructional strategy.

1. *What is the effect of differential grouping practices on conceptual understanding?*
2. *What is the effect of differential grouping practices on critical thinking skills?*
3. *What is the effect of constructivist teaching methods on conceptual understanding?*
4. *What is the effect of constructivist teaching methods on critical thinking skills?*
5. *What is the effect of traditional teaching methods on conceptual understanding?*
6. *What is the effect of traditional teaching methods on critical thinking skills?*

7. What are the combined effects of matching strategies, constructivist or traditional with grouping practices on student conceptual understanding?

8. What are the combined effects of matching strategies, constructivist or traditional, with grouping practices on student critical thinking skills?

Population and Sample

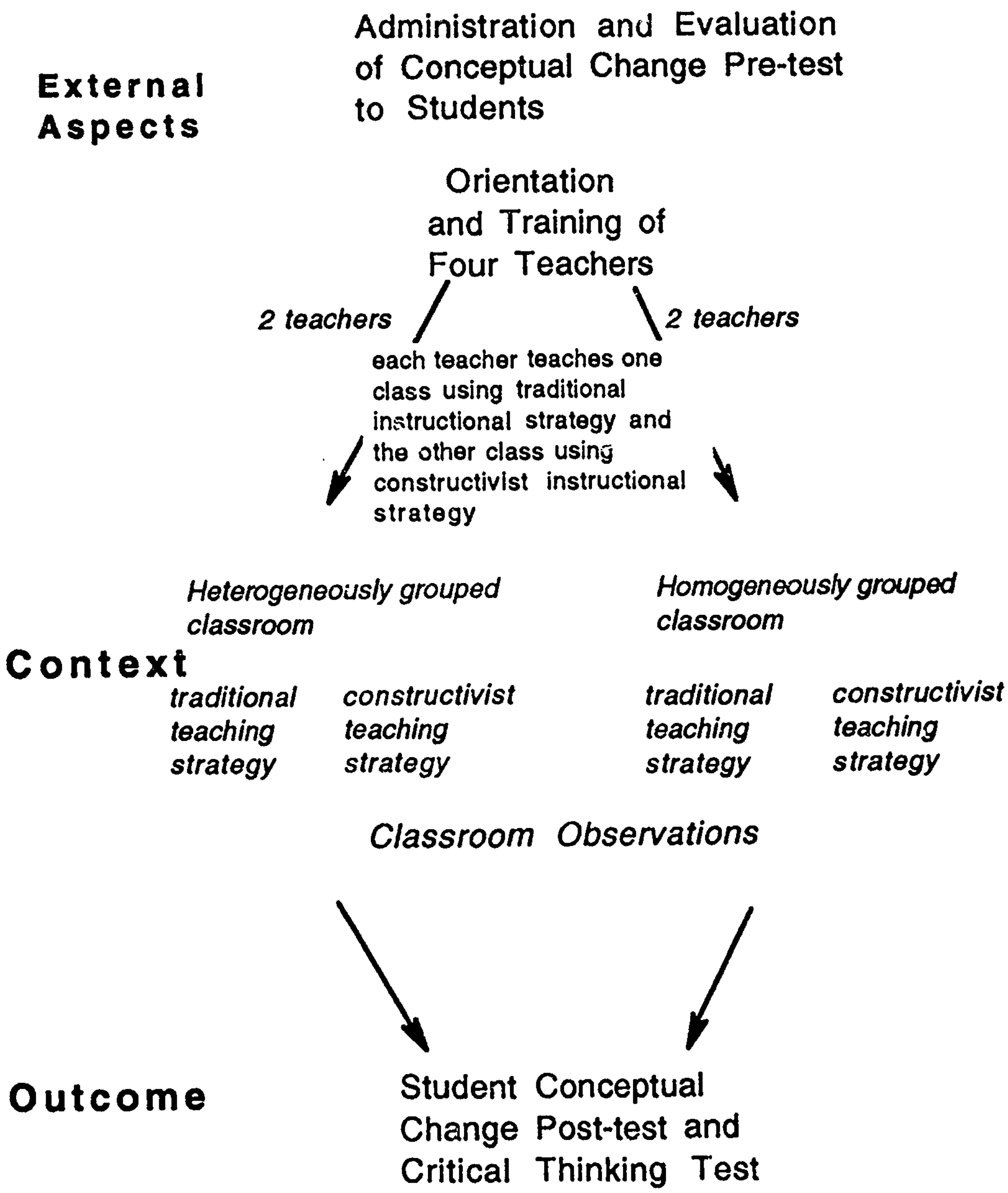
Three high schools were included in the study. The schools are located in the New England region of the United States. Each school district may be described as suburban rural and predominantly middle class. One school (High School C) offered heterogeneously grouped biology classes. The other two schools (High School A and High School B) grouped their classes homogeneously. In order to control for environmental variables, effort was made to match school demographics and populations, curricula content and materials, and to have the units taught during the same time period.

Instrumentation

Conceptual Understanding

All students were pre and post-tested for conceptual understanding using a two-tier multiple choice test developed by Haslam and Treagust (1987). The test consisted of 13 items with a reliability of 0.72 (Cronbach's coefficient alpha) and a readability between 7 and 8 year level (Fry's Readability Graph). Content validity was established by matching propositional knowledge statements about photosynthesis and respiration with each test item.The first tier is a multiple choice content question followed by a second tier of multiple choice reasons for the answer given in the first tier. The reasons consisted of scientifically acceptable answers and identified alternative conceptions. Space is also provided for students to give reasons that differ from the reasons provided.

Figure 1. Conceptual model of the study



Critical Thinking

The plant nutrition portion of The Critical Thinking in Biology Test (TCTB) was used to assess the critical thinking skills of the students The alpha reliability coefficient for TCTB is 0.83. Concurrent validity of TCTB is supported by r values of 0.68 with tne Natural Science section of the ACT test and 0.64 with Watson and Glaser's Critical Thinking Appraisal test (McMurray, Beisenhorz, & Thompson, 1991).

Classroom Observations and Survey

In order to ensure adherence to constructivist versus traditional approaches, the investigator visited the classrooms and observed the teaching/learning process. Observational data was compiled using the Science Classroom Rubric (SCOR) (Burry, Sunal, Turner, & Pittman, 1993). This observational tool was specifically designed to assess adherence to constructivist teaching strategies . An analytical scoring system of a 1 (low) to a 5 (high) rates the degree to which teacher behaviors reflect constructivist teaching. The SCOR identifies four categories that represent a constructivist perspective of classroom instruction; facilitating learning process, content specific pedagogy, contextual knowledge, and content knowledge. Reliability for SCOR total was .91 and varied from .80 to .89 for each of the four factors. Construct validity was established using a factor analysis, an Item Response Theory analysis, and known group approach. For this study, a high score using the SCOR indicated that the teacher was exhibiting constructivist teaching behaviors, whereas a low score indicated that the teacher is exhibiting traditional teaching behaviors.

Classroom observations were conducted by videotape. At the minimum, each class was observed and videotaped three times. The videotapes were analyzed by the researcher using SCOR for adherence to the prescribed instructional strategy. To ensure instrument reliability and to avoid researcher bias, randomly selected videotaped classes were observed and analyzed by a high school department chairperson, experienced in classroom observation and evaluation. After intercoder agreement was established (.97), the researcher coded the remaining videotapes.

Teacher Training and Implementation

Teachers involved in the study underwent 4 hours of training on administering the assessment tests and teaching the plant unit. The researcher met with the teachers one month before the start of the study. At the first meeting the teachers were given copies of the constructivist curriculum and the traditional curriculum. The researcher discussed with the teachers the instructional methods and philosophy of each method. Each teacher was given a table by Brooks and Brooks (1993) that defines and delineates the two methodologies. Teachers were asked to review the curriculum materials. At the next meeting, the researcher addressed and clarified any questions regarding the curricula. Before the beginning of the study, one class of each teacher was videotaped and analyzed using SCOR. The analysis was discussed with individual teachers. When necessary, suggestions for improving a particular strategy were made. Finally, instructions for administering the conceptual change test and the critical thinking test were given.

Curriculum Materials

Teachers using the constructivist approach followed a modified constructivist teaching sequence adapted from Driver and Bell (1986) and described in the CLIS Approaches to Teaching Plant Nutrition (1987). Teachers using a traditional approach used Miller and Levine's (1995) Biology textbook generated unit on plant nutrition. The traditional science classroom instruction was characterized by a fixed, fact based curriculum, didactic teaching, teacher centered instruction, indivi⁚ al student work, and pen and paper assessment. The constructivist science classroom is characterized by a flexible, concept based curriculum, student centered learning, hands-on activities, group work, and ongoing, alternative assessment through student exhibitions. Each unit consisted of 6 lessons that encompassed 12 classroom periods

Analysis of Data

The unit of analysis was the biology classroom. Data were analyzed based on main effects (grouping or instructional strategy) and interaction effects (grouping by instructional strategy) using an analysis of variance for pretest scores and an analysis of covariance for the conceptual change post-test and for The Critical Thinking in Biology Test. Paired t-tests were performed to compare the means of the pretest and post-test scores of conceptual change.

By definition homogeneous and heterogeneous classroom imply inequality in variance of the population. In homogeneous classrooms, it is assumed that students are grouped according to previous science achievement, whereas, heterogeneous grouping assumes different science achievement levels. Also, the investigator used intact groups for the study, which negated randomization of the groups. Consequently, analysis of covariance (ANCOVA) using pretest scores of conceptual change was selected to compensate, in part, for this factor. The uncontrolled variable, or covariate will be the pre-test score on the test of conceptual understanding. Although the classes were heterogeneously grouped and homogeneously grouped, thus implying academic differences between the classes, student understanding of plant nutrition concepts was not significantly different between the two populations. The dependent variables were conceptual understanding test scores and critical thinking test scores.

Paired t-tests were also performed on the means of four groups (heterogeneous constructivist, heterogeneous traditional, homogeneous constructivist, and homogeneous traditional) comparing the pretest and the post-test of conceptual change.

Results

Descriptive data of the conceptual change pre-test, the conceptual change post-test, and the critical thinking test in biology suggested that there are some differences among the classes studied (see Table 1).

The heterogeneous classes scored higher than the homogeneous classes in both the pretest and the post-test of conceptual change. Interestingly, one group, homogeneous constructivist, showed a decrease in the mean score on the conceptual change post-test. There does not seem to be a difference between the constructivist and traditional groups on conceptual change. Among the four groups there does not seem to be any difference in critical thinking scores.

Further analysis of data included a two-way analysis of variance, on the pretest scores, a two way analysis of covariance on post-test and critical thinking test scores, using the pretest as covariate, and paired t-tests for pretests versus post-tests. The analysis of variance test was performed to discern any differences between the groups. Since intact groups were used for the study, the analysis of covariance (ANCOVA) was used to adjust for initial differences. The uncontrolled variable, or covariate, was the pretest score on the test of conceptual understanding. Paired t-tests were performed to indicate the direction and magnitude of the mean differences in each group.

Table 1
Means and (Standard Deviations) for Each Type of Class and Each Test

Class	Conceptual Change Pretest	Conceptual Change Post-Test	Critical Thinking Test
heterogeneous constructivist n=31	42.48 (13.30)	47.94 (12.21)	30.74 (25.23)
heterogeneous traditional n=24	40.21 (16.89)	49.96 (17.28)	23.21 (28.48)
homogeneous constructivist n=32	33.31 (14.83)	30.94 (14.49)	27.53 (22.71)
homogeneous traditional n=39	30.51 (10.94)	32.00 (15.69)	25.95 (21.31)

Although the classes compared were heterogeneously and homogeneously grouped, it was thought that student understanding of plant nutrition concepts should not be significantly different. This assumption was invalid since an ANOVA of pre-test scores showed a significant f value ($F=14.27$; $p<.0001$) for the main effect of grouping, but not for instructional strategy or interaction effects (see Table 2). This implies that there were differences in the understanding of the concepts of plant nutrition between the homogeneously grouped students and the heterogeneously grouped students.

Using an two way analysis of covariance, a significant effect for grouping was found (F=27.14; p<.0001). There was a significant F ratio for regression (F=15.09; p<.0001), which means that the relationship between the covariate , the pretest and the dependent variable, the post-test was not likely to have occurred by chance (see Table 3). Therefore, the pretest scores do covary with the dependent variable, the post-test results.

Table 2
Two - way Analysis of Variance of Conceptual Change Pre-test Scores

Source	SS	*df*	MS	F ratio	P
Grouping	2718.98	1	2718.98	14.27	.000
Instructional strategy	205.72	1	205.72	1.08	.30
Grouping X Instructional strategy	2.10	1	2.10	.01	.92
Residual	23240.32	122	190.49		

Although there were initial differences indicated by the ANOVA for the pretest scores, the regression analysis indicated that there is a relationship between the covariate, the pre-test of conceptual change, and the dependent variable, the post-test of conceptual change.

An analysis of covariance on the conceptual change test showed no significant effect for the main effect of instructional strategies or the interaction effect for grouping and instructional strategies (see Table 3). It appeared that grouping was the only variable that affected conceptual change.

Table 3
Two - way Analysis of Covariance of Conceptual Change Post-test Scores

Source	SS	*df*	MS	F ratio	P
Within Cells	24189.51	121	199.91		
Regression	3017.19	1	3017.19	15.09	.000
Grouping	5425.85	1	5425.85	27.14	.000
Instructional strategy	183.04	1	183.04	.92	.341
Grouping X Instructional strategy	4.55	1	4.55	.02	.88

An analysis of covariance on the critical thinking test showed no significant main effect or interaction effect for grouping and instructional strategies. The regression analysis found that the covariate, the pretest was not significant. Therefore, any differences in the critical thinking test scores were not related to the pretest scores (see Table 4).

Since the ANOVA and ANCOVA tests could be masking the effects of either the instructional strategy or the grouping climate, paired T tests were performed on four groups; heterogeneous constructivist, heterogeneous traditional, homogeneous constructivist, and homogeneous traditional. The test compared the means of the groups on the pretest of conceptual change with the means of the post-test of conceptual change. A significant effect (alpha =.0.05) for the conceptual change test was found for the heterogeneous traditional group (t=2.42; p =.016). The heterogeneous constructivist, showed a significant T score (t=2.21; p=.031) for the conceptual change post-test (see Table 5). Heterogeneous grouping was the common factor affecting conceptual change.

Table 4
<u>Two - way Analysis of Covariance of Critical Thinking Test Scores</u>

Source	**SS**	***df***	**MS**	**F ratio**	**P**
Within Cells	69809.28	121	576.94		
Regression	1188.48	1	1188.48	2.06	.154
Grouping	185.31	1	185.31	.32	.572
Instructional strategy	8.07	1	8.07	.01	.906
Grouping X Instructional strategy	65.64	1	65.64	.11	.736

Table 5
Paired t-test of Pre-test and Post test Scores on Conceptual Change

Class Type	Pretest mean	Post-test mean	t ratio	two-tailed probability
heterogeneous constructivist n=31	42.48	47.94	2.42	.031
heterogeneous traditional n=24	40.21	49.96	2.61	.016
homogeneous constructivist n=32	33.31	30.93	2.56	.452
homogeneous traditional n=29	30.52	32.00	1.49	.587

The quantitative data and analyses indicated that grouping alone was one factor affecting conceptual change. Instructional strategies did not affect conceptual change test scores. There was no significant effect when grouping and instructional strategy were combined. Critical thinking scores were not affected by grouping, instructional strategy or the interaction of both.

The interpretation of analysis of variance and analysis of covariance contain certain assumptions. The first assumption states that the variance between the groups is homogeneous. The p value associated with the tests is large enough that the homogeneity of variance of assumption is not rejected. Therefore this assumption is met and interpretation of the ANOVA test is valid. (see Table 6).

Table 6
Tests of Homogeneity of Variance

Test	Value	Probability
Cochran's C	5	.247
Bartlett Box F	1.336	.248
Hartley's F Max	1.344	

Two other assumptions should be met in order to perform an Analysis of Covariance procedure. Since ANCOVA is a combination of ANOVA and regression analysis, one must assume that homogeneity of regression exists between groups and that the regression coefficient for the covariate and dependent variable is not zero.

A test of homogeneity of regression between groups (heterogeneous versus homogeneous) provided an F value =.50; p=.480. This F value is not significant, therefore we fail to reject the hypothesis of homogeneity of regression. One may assume, therefore, that the regression coefficients for the groups are similar.

The covariance model assumes that the covariate (the pretest) is associated with the dependent variable (the post-test. or the critical thinking test). This assumption was met for the conceptual change post-test ANCOVA (regression = 15.09; p< .0001) but not for the critical thinking test ANCOVA (regression =2.06; p=.154) (see Tables 3 and 4).

Since the assumptions were met for the conceptual change test, the ANOVA and ANCOVA results indicating a significant effect of grouping on conceptual change scores were valid. Since there was no relationship between the covariate (pretest) and the dependent variable (critical thinking) the nonsignificant results of the ANCOVA on the critical test thinking test were explainable.

Class Composition Information

In as much as grouping practices appeared to be a factor in influencing students' conceptual change and given the fact that grouping practices describe the academic makeup of a classroom, it seemed appropriate to investigate the composition of each class based on students' academic background in science and math. In this study, homogeneous or like ability grouping included any deliberate attempt to group students by academic ability or intelligence measure (i.e. I.Q., science scores, math scores), whereas heterogeneous or mixed ability grouping places students in the same classroom regardless of perceived academic ability. Information was collected through a survey listing each students mathematics class and science class from the previous school year. In the heterogeneous classes the majority of the students were enrolled in Algebra IC (49.28%) with the the remaining students being enrolled in Pre-Algebra S (2.89%), Algebra 2H (13.04%), and Basic Algebra S (17.39%) Similarly, the majority of students (71.19 %) were enrolled in the college level Introduction to Physical Science (I.P.S.), followed by 22.04 % in the standard level Physical Science, and 3.39 % in honors level I.P.S and 3.39% in other science classes (see Table 7).

The data from the homogeneosly grouped classes seemed to paint a slightly different academic picture of the classroom. In High School A, 29.63 % and 33.33% reported being in college mathematics and science respectively last year. The remainder of the students were enrolled in standard level mathematics or science classes the previous year (see Table 8)

Table 7
Composition of Heterogeneous Classes Based on the Previous Year's Mathematics and Science Enrollments

Mathematics Class	# of students	Percent	Science Class	# of students	Percent
Pre-Algebra S	2	3.39	Physical Science S	13	22.03
Basic Algebra S	8	13.56	I.P.S.C	42	71.19
Algebra 1 C	36	61.02	IPS H	2	3.39
Algebra 2H	13	22.03	other	2	3.39
Total	59		Total	59	

Table 8
Composition of Homogeneous Classes (High School A) Based on the Previous Year's Mathematics and Science Enrollments

Mathematics Class	# of students	Percent	Science Class	# of students	Percent
Intro Algebra S	15	55.56	Meteorology/ Geology S	14	51.85
Algebra 1 C	8	29.63	Oceanography/ Astronomy C	9	33.33
Basic Math S	1	3.70	none	2	7.41
Business Math S	3	11.11	other	2	7.41
Total	27		Total	27	

In High School B 86.09% of the students reported being enrolled in a standard level science class. A guided learning class and an advanced level class each accounted for 6.82 % of the previous year's enrollment. A large majority (89.64%) of the students reported being enrolled in a standard mathematics course. Only 11.36 % were in a GL level mathematics course. No one reported taking a college level mathematics (see Table 9).

Table 9
Composition of Homogeneous Classes (High School B) Based on the Previous Year's Mathematics and Science Enrollments

Mathematics Class	# of students	Percent	Science Class	# of students	Percent
General Math GL	5	11.36	I.P.S. GL	3	6.82
Pre-algebra S	9	20.46	I.P.S. S	32	72.73
Algebra 1 S	23	52.27	I.P.S. A	2	4.54
Algebra 2 S	3	6.82	Biology S	3	6.82
Geometry S	4	9.09	Biology A	1	2.27
			Other S	2	4.54
			none	1	
Total	44		Total	44	

When data from both High School A and High School B were combined it seemed obvious that the majority of students presently in standard (non-college) biology were also grouped in the same level science and math (77.27 % and 81.69 % respectively) the previous year. Therefore, the assumption that schools which group students based on previous ability in science and math was valid. The homogeneously grouped classes reflected an attempt to group students by academic ability.

The heterogenous classes studied demonstrated a range of abilities and experiences in science and mathematics. Students were placed in the same classroom regardless of perceived academic ability. The highest percentage of students in the heterogenously grouped classes were enrolled in college level science and mathematics classes (71.19 % and 61.02 % respectively) during the previous year. Although this may appear more homogeneous than heterogeneous, the remainder of the class composition arose from both non-college and honors levels. This differed from the absence of any honors mathematics or science enrollees and the paucity of college level students in the homogeneous classes.

A descriptive analysis of the classrooms studied indicated that there were differences between the classes that were hetrogeneously grouped and the classes that were homogeneously grouped. In general, the heterogenous classes contained students from different backgrounds in science and mathematics whereas the homogeneous classes contained students who had similar experiences in science and mathematics.

Classroom Observation Information

Although instructional strategies were not found to affect conceptual change or critical thinking, an analysis of the strategies used in each classroom did provide additional information to supplement the quantitative results. Each teacher was observed, videotaped and analyzed using the Science Classroom Observation Rubric (SCOR) at least 6 times during the course of the study. This observational tool was specifically designed to assess adherence to constructivist teaching strategies.

The teachers were designated as follows;

teacher 1 - homogeneous class school B

teacher 2 - homogeneous class school A

teacher 3 - heterogeneous class school C

teacher 4 - heterogeneous class school C

As seen in Tables 11 and 12 teaching practices observed, as determined by SCOR, varied from teacher to teacher and from class to class. In all but one case, the teacher scores in the class designated constructivist were higher than the scores attributed to the traditional class. This indicated that the teaching practices were adhering to constructivist guidelines as measured by SCOR. In the one exception, teacher 1, the first traditional classroom observation was a

67, two points higher than the second constructivist class observation. After a brief discussion with teacher 1, the teaching practices for the next two observations more clearly reflected traditional practices. The degree of adherence to constructivist practices varied from teacher to teacher from a low of 68.35 to a high of 80.66 (out of a possible 90 points). The homogeneous classes averaged 74.5 for the constructivist classes and 61 for the traditional classes. The heterogenous classes averaged a score of 78 for the constructivist classes and 51 for the traditional classes (see Tables 10 and 11).

Table 10

Classroom Observation Data using Science Classroom Observation Rubric (SCOR) for Teachers 1 and 2 (Homogeneous)

	Teacher 1		Teacher 2	
scores	constructivist class	traditional class	constructivist class	traditional class
1	69	67	84	72
2	65	48	75	70
3	71	42	83	67
average	68.35	52.33	80.66	69.66

Even though the quantitative results did not indicate a significant effect of instructional strategy on conceptual change or critical thinking, the teacher observations did indicate that the strategies used by each teacher adhered to the prescribed strategy for the class. The degree of adherence to each strategy did vary from teacher to teacher and yet the observation scores for each class type, homogeneous versus heterogeneous, were similar.

Table 11

Classroom Observation Data using Science Classroom Observation Rubric (SCOR) for Teachers 3 and 4 (Heterogeneous)

	Teacher 3		Teacher 4	
scores	constructivist class	traditional class	constructivist class	traditional class
1	83	40	83	57
2	80	39	76	61
3	69	47	80	65
average	77.3	42	79.66	61

Discussion

The results indicated that grouping practices had a significant effect on conceptual understanding. Although the survey data indicated that the class composition differed between the heterogeneous and homogeneous classes, these classes should not have been significantly different in their understanding of photosynthesis. The students in the study had not had any previous high school experience or exposure to the topic of plant nutrition. Therefore, one would expect that the classes would not significantly differ on the pretest scores. Surprisingly, an ANOVA indicated that the classes did differ significantly in pretest scores. It is unclear why this discrepancy in the knowledge of plant nutrition existed. Any previous school-based exposure to the topic of plant nutrition must have occurred prior to the students' entering high school.

Since the groups used in the study were intact groups, an ANCOVA was used to analyze the dependent variables (conceptual change and critical thinking) using the pretest as the covariate.

The ANCOVA results for the post-test scores indicated that there was a significant main effect for grouping, no significant main effect for instructional strategy or interaction effect for grouping by instructional strategy. Paired t-test results on conceptual change post-test mean scores showed a significant t-score for the heterogeneous classes. The ANCOVA for the critical thinking in biology scores showed no significant main effect for grouping, instructional strategy, and no significant interaction effect for grouping by instructional strategy.

The results of this study indicated that after instruction students in the heterogeneous classes understood more about plant nutrition than their homogeneously grouped peers. These results contradict the findings of Plewes (1979), Hacker and Rowe (1994) and Kulik and Kulik (1982). Based on science achievement scores, Plewes (1979) concluded that the homogeneous groups performed better than the heterogeneous groups. Hacker and Rowe (1994) noted that there was a decrease in student interactions as measured by the Science Lesson Analysis System (SLAS), in the heterogeneous classroom. Kulik and Kulik's (1982) meta-analysis indicated that ability grouping improves academic achievement. In contrast, the results of this study are consistent with the findings of Slavin (1990), Gamoran (1986), Alexander, Cook and McDill (1978), Hoffer (1994), and Kerchoff (1986). Slavin's meta-analysis stated that there is no academic advantage to grouping students of similar abilities over grouping students of mixed abilities. The studies by Gamoran (1986), Alexander, Cook and McDill (1978), Hoffer (1994), Kerchoff (1986) concluded that homogeneous grouping either has no effect or a deleterious effect on academic achievement of the lower ability student. The present study provides further evidence that ability grouping can have a negative effect on academic achievement, whereas mixed ability grouping can improve academic achievement.

It appears that the heterogeneously grouped classes provided an environment in which students could learn a difficult scientific topic, such as plant nutrition. Lumpe and Staver (1995) hypothesized that peer collaboration in heterogeneously mixed groups may assist students in developing an understanding of scientific concepts. The sharing and feedback evidenced within the experimental groups in their study helped students acquire an understanding of plant nutrition. Although the present study attempted to minimize group and peer interaction in the traditionally taught classrooms, the heterogeneously grouped classes still scored significantly higher on the conceptual change post-test.

The homogeneous classes used in the study contained students grouped below a college preparatory level. In most cases the students had been previously enrolled at this level in math and science. Oakes' (1985) and Gamoran and Berends' (1987) studies indicated that low tracked classrooms promote a negative classroom climate, characterized by anti-school behavior, defeatist attitudes, and alienation on the part of the students. It is possibly that some of factors could have been exhibited by the students in the grouped classes and have affected their ability to learn the material.

Although student understanding of plant nutrition improved significantly in heterogeneously grouped classes, student ability to think critically was not affected by grouping, instruction or an interaction of the two factors. Though the critical thinking in biology test questions chosen for this study focused on plant nutrition, students' inability to apply critical thinking skills did not appear to impact on their conceptual understanding of photosynthesis. A likely interpretation of these results is that the the development of critical thinking skills can not be accomplished in a short time period regardless of the instructional strategy used or the grouping climate involved. Also, classroom instruction did not overtly focus on the development of critical thinking skills. The researcher was interested in determining whether common grouping practices and/or two instructional strategies could affect critical thinking. Previous studies had indicated that heterogeneous grouping, and constructivist teaching could improve critical thinking skills (Johnson & Johnson,1979; Johnson, Johnson, Holubek, & Roy,1984; Resnick,1992; Zohar, Weinberger & Tamir, 1994). Zohar, Weinberger, and Tamir (1994) stated that a student-centered classroom provides the necessary conditions for promoting the development of critical thinking. Yet, they also concluded that instruction must be expicitly and deliberately designed to foster critical thinking skills. Also, it would appear that the two to three week time period of this study was not enough time to observe a significant change in critical thinking skills.

Despite research to the contrary (Brooks & Brooks, 1993; Hand & Treagust, 1991; Hewson & Hewson, 1983; Oldham, Driver & Holding, 1991; Purser & Renner, 1983; Schneider & Renner, 1980; Smith, Blakeslee, & Anderson, 1993), the constructivist teaching strategies used in this study did not improve conceptual understanding or student ability to think critically. Although the Oldham, Driver, and Holding (1991) study was flawed due to poorly matched groups, they found that students taught using the Childrens Learning in Science approach scored significantly better on a test of conceptual understanding of plant nutrition than their traditionally taught peers after one unit of instruction. Two studies, Schneider and Renner (1980) and Purser and Renner (1983), showed that concrete versus formal teaching sequences covering 12 weeks and 8 months respectively can improve science content achievement. Hand and Treagust's (1991) study indicated that a constructivist teaching strategy can improve problem solving skills. Hewson and Hewson (1983) found that students taught using a constructivist sequence scored higher on all but one topic, density, than the control group. Smith, Blakeslee and Anderson's (1993) study focused on the relationship between teachers' use of observed strategies and student learning of three biology units as measured by conceptual change oriented test. Statistically significant correlations were found between student learning and conceptual change strategies. It may be that the two to three week time period of this study was not enough time to discern a significant effect of constructivist teaching strategies on conceptual understanding or critical thinking skills. Also, the constructivist teaching strategies used in this study were adapted from the CLIS curriculum and modified for use in a 45 to 90 minute classroom period. It is likely that an effective constructivist teaching strategy must be comprehensive and long term in order to significantly affect conceptual change and critical thinking.

Limitations of this Study

This study investigated the effectiveness of the grouping climate and the instructional practices of the science class with hopes of linking science education reform policy with classroom practice. For this reason, it was important to use intact classrooms in the study.

The use of intact classrooms for this study presented some challenges. Random assignment of students to the classes studied was not possible or expected. Student numbers varied from class to class. The time allotted for each class period varied from school to school. The study was restricted to one unit due to time and curriculum coverage concerns. The use of the ANCOVA method for data analysis controlled for the non-random classroom assignments, as well as the differing class sizes. The length of treatment and the amount of time allotted each class period must be considered when interpreting the results of this study.

An additional area of concern is the ability of the teachers in the study to effectively change instructional strategies within one or two school days. The behaviors and conditions that define and describe a constructivist classroom versus a traditional classroom represent very different views as delineated by Brooks and Brooks (1993). Traditional instructional strategies are based on a behaviorist view of teaching and learning, whereas the constructivist view arises from the conceptual change literature and the learning theories of Ausubel and Piaget. It is assumed that there is a relationship between teacher classroom behavior and teacher beliefs concerning teaching and learning. Therefore, one would suspect that a teacher who holds behavorist beliefs would have difficulty teaching in a constructivist manner and a teacher who holds constructivist beliefs would have difficulty teaching in a behaviorist manner.

Although this could be a confounding variable in interpreting the results of this study, the observational analysis and a study by Lederman and Zeidler (1987) contradicted this assumption. The observational data collected indicated that the teachers involved in this study were able to change classroom behaviors according to the prescribed instructional strategy. The study by Lederman and Zeidler (1987) found that teachers' beliefs about the nature of science were not related to their classroom behaviors.

Internal validity

An area of concern in interpreting the results is the different class times from school to school. Although the total time spent on the unit was the same, the length of class time and the number of times the class met per week or cycle differed. The homogeneous classes in High School A and High

School B met for forty-three minutes and forty-five minutes respectively. In High School A classes met every day. In High School B the classes met five days out of a six day cycle. The heterogeneous classes in High School C met for ninety minutes, every other day. Recent school reform literature advocates the scheduling of longer class meeting times as a means to improve learning (Sizer, 1992). Advantages to scheduling science classes for ninety minutes include having more time to perform laboratory activities, to work cooperatively, to engage in discussions, to assess student work, to provide follow-up, and to explore topics in greater depth. (Day, 1995; Gerking, 1995). When interpreting the results of this study one must consider the fact that the heterogeneous classes were also the classes that met for ninety minutes.

External validity

The generalizability of the results of this study may be affected by the length of treatment and the definitions used for homogeneous versus heterogeneous grouping.

The two to three week time period may not be enough time to produce significant changes in critical thinking skills. Effective thinking skills programs encompassed longer time periods ranging from 24 class periods to an entire school year (Collea & Nummedal, 1979; Tomlinson-Keasey & Eisert, 1977; Zohar, Weinberger, & Tamir, 1994). Similarly the implementation of a particular instructional strategy for two to three weeks may be a insufficient time period to significantly affect conceptual change. The minimum amount of time spent on a constructivist lesson that demonstrated significant conceptual change by the students was for three months (Smith, Blakeslee, & Anderson, 1993). Other studies that concluded that a constructivist teaching sequence can affect conceptual change encompassed twelve weeks and eight months of the school year (Purser & Renner, 1983; Schneider & Renner, 1980).

Heterogeneous grouping and homogeneous grouping mean different things to different people. In this study, homogeneous or like ability grouping included any deliberate attempt to group students by perceived academic ability or intelligence measure (i.e. I.Q., science scores, math scores) whereas heterogeneous or mixed ability grouping included the placement of students in the same classroom regardless of perceived academic ability. Perceived academic ability was assessed by surveying student enrollment in the previous years mathematics and science classes. Most of the students in the homogeneously grouped non-college biology classes had been enrolled in non-college science and math courses. The heterogeneously grouped biology classes included a majority of students previously enrolled in college level science and mathematics, but also included students from non-college level science and mathematics from honors level science and mathematics course. The definition of heterogeneity and homogeneity used in this study may not be applicable to other secondary school settings. In drawing conclusions or generalizations from these results one must consider the context of this study.

Implications for Future Research

Despite the concerns mentioned, the results of the study indicated that heterogeneous grouping significantly improved conceptual change in the biology classroom. It appeared that the environment of the heterogeneous classroom promoted learning. In the future, research should include observations and analysis of the heterogeneous classroom. As suggested by Gamoran and Berends (1987) the research should combine both quantitative as well as qualitative information. Observational data should include analysis of the quality and quantity of student to student interactions and student to teacher interactions. Although Hacker and Rowe's (1994) study on grouping and instructional strategies found a deterioration in high ability students interactions in the heterogeneous classroom, the results of this study supports the use of the Science Lesson Analysis System to reinvestigate the instructional climate of the heterogeneous classroom.

Additionally, instructional strategy studies should focus on investigating the effects of the long term use of a particular strategy. The minimum time spent on a constructivist lesson that demonstrated a significant change was 3 months (Smith, Blakeslee, & Anderson, 1993). Critical thinking programs characteristically cover a semester or more. The difficulties inherent in conceptual change and in the development of critical thinking require a comprehensive, long term approach. It is recommended that research into the effectiveness of instructional strategies include a school period of 3 months or more.

Further studies investigating the effectiveness of particular instructional strategies should take into account teacher beliefs concerning teaching and learning. The effectiveness of a particular instructional approach may be compromised by an inadequate or mismatched belief system.

Although this study did not find a significant effect on conceptual change or critical thinking for the interaction of instructional strategy and grouping, future research on instructional strategies, particularly constructivist teaching sequences, should include information concerning the grouping climate of the classes studied. While the conclusions of the grouping research literature are mixed, it appears that the grouping climate can affect student achievement outcomes (Alexander, Cook, & McDill, 1978; Gamoran, 1986; Gamoran & Berends, 1987; Hoffer, 1992 ; Kerchoff, 1986; Kulik & Kulik, 1982; Slavin, 1990; Oakes ,1985; Hacker & Rowe, 1993; Plewes, 1979).

Future research studies should match classrooms based on class time periods. Recent reports suggested that longer class time blocks can improve learning (Day, 1995; Gerking, 1995). The longer class times may provide students with more opportunities to engage in activities that can promote conceptual change and critical thinking skills.

Conclusion

This study attempted to fill the gaps in the research literature by investigating the separate and combined effects of traditional and constructivist instructional strategies and homogeneous and heterogeneous grouping climates in the science classroom. The grouping literature lacked information about instructional strategies. Conversely, the instructional strategy literature neglected to include information on the grouping climate of the classroom.

The results of this study indicated that heterogeneous grouping alone can significantly affect conceptual understanding of plant nutrition. There was no interaction effect of instructional strategy and grouping on conceptual change or critical thinking. Therefore, questions in the research remain. Future studies should investigate the quality and quantity of the student to student interactions and the student to teacher interactions that occur in the heterogeneous classroom in order to identify and document the classroom activities and characteristics that promote learning. Research on the effectiveness of a instructional strategy, particularly a constructivist teaching sequence, in promoting conceptual change and/or critical thinking skills should focus on long term, comprehensive use of the instructional strategy. In as much as this study did not demonstrate an interaction effect between grouping and instructional strategies, that area remains open to investigation for future long term studies

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