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AUTHOR	Smith, Leslie A.; Bitner, Betty L.
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ABSTRACT

The purpose of this study was to determine the influence of an STS curriculum (ChemCom) versus a traditional chemistry curriculum (GenChem) on student formal reasoning level. Cluster random sampling was used to select the sample (N=123). Gender differences in formal reasoning level were also investigated. The abbreviated GALT pretest was administered to students enrolled in a ChemCom curriculum (n=63) and a GenChem curriculum (n-60). A GALT posttest was administered after treatment. ANCOVA and chi-square statistical tests were used to analyze differences between the two curricular approaches and between gender, respectively. No significant differences were indicated with males outscoring females on both pretest and posttest scores. (Author)

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COMPARISON OF FORMAL OPERATIONS: STUDENTS ENROLLED IN CHEMCOM VERSUS A TRADITIONAL CHEMISTRY COURSE

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Leslie A. Smith
Chemistry teacher - Kotzebue High School
P.O. Box 251
Kotzebue, Alaska 99752
(907) 442-3341 or FAX (907) 836-2141

Betty L. Bitner
Department of Curriculum Instruction
Southwest Missouri State University
901 South National
Springfield, Missouri 65804
(417) 836-5000 or FAX (417) 836-4884

ABSTRACT

The purpose of this study was to determine the influence of an STS curriculum (ChemCom) versus a traditional chemistry curriculum (GenChem) on student formal reasoning level. Cluster random sampling was used to select the sample ($N = 123$). Gender differences in formal reasoning level were also investigated. The abbreviated GALT pretest was administered to students enrolled in a ChemCom curriculum ($n = 63$) and a GenChem curriculum ($n = 60$). A GALT posttest was administered after treatment. ANCOVA and chi-square statistical tests were used to analyze differences between the two curricular approaches and between gender, respectively. No significant difference was found between groups. Gender differences were indicated with males outscoring females on both pretest and posttest scores.

Introduction

A variety of research evaluating high school science curricula during the 1970s and the 1980s determined that the main justification for including science in the school program is its value in preparing persons for further study (Brunkhorst & Yager, 1985; Harms & Yager, 1981; National Science Foundation [NSF], 1979; National Science Teachers Association [NSTA], 1982). While this justification is appropriate for the 1.5% of high school graduates who graduate from college with a science or engineering degree, the other 98.5% of the students required to take science are ill-served, posing one of our greatest problems in education (Brunkhorst & Yager, 1985). The latter students study science because specific courses are listed as prerequisites for graduation or for specific career choices, yet they find no real value in the course itself (Brunkhorst & Yager, 1985). This lack of relevancy has caused science educators to redesign traditional science courses to incorporate aspects of the "real world" with societal and technological aspects relevant to the individual student's life and future choices. Courses of this sort are described as Science-Technology-Society (STS) curricula. These courses assert that the major goal of science education is to develop scientifically literate individuals who understand how science, technology, and society interrelate and who are able to use this knowledge in everyday decision-making (NSTA, 1982).

While students can respond to questions on examinations, including the solution of mathematical problems, much of this success with course materials is unrelated to real world experiences (Harms & Yager, 1984). It has been observed that science has become too specialized, too uncommon, too abstract, and too unrelated to the real experiences of most students. Science does not provide the organization or vehicle necessary for students to understand the relationship between science and technology (Brunkhorst & Yager, 1985).

Recent textbooks and curricular designs have been directed toward the STS approach in science. One example is the Chemistry in the Community (ChemCom) curriculum. ChemCom strives to enhance science literacy through a high school curriculum emphasizing the impact of chemistry on society (Nelson, 1988). Traditionally, chemistry courses concentrate on educating the student for success in college science courses. These courses are generally implemented through a lecture/laboratory/problem-solving strategy
assuming that the majority of students have attained formal operational reasoning skills.

As many of the societal issues of the day rely to some extent upon the research of scientists, it is sad to note that the number of high school

students that voluntarily choose to take science courses is at a historic low (Nelson, 1988).

Problem and Questions

The primary purpose of this study was to compare the influence of he Ch mCom STS curriculum and the traditional lecture/laboratory/problem-solving style used in general chemistry on the acquisition of logical thinking skills. The second purpose of this study was to investigate gender differences in reasoning level.

Research Questions

1. Is there a significant difference in student gain of formal operational thinking in courses using the STS approach (ChemCom) versus courses using the traditional chemistry teaching style (GenChem)?

2. Is there a significant difference in reasoning level of students in ChemCom versus GenChem?

3. Are there gender differences in reasoning abilities of high school chemistry students?

Assumptions

The following assumptions were made in this study:

1. It is assumed that all teachers administering the Group Assessment of Logical Thinking (GALT) followed the directions provided for the administration of the test.

2. It is assumed that all teachers participating in the study comply with the Major Instructional Goals that are pre-scribed by the sampled school system for the ChemCom group and the GenChem group, thus generalizing the information presented to all students involved.

Limitations

The following limitations were acknowledged in this study:

1. Teachers whose classes were used in this study may have varying degrees of effectiveness in promoting student learning. No attempt was made to control individual teaching styles or student learning style

2. Students already possessing formal operational skills at the onset of the study may indicate no significant change.

3. Due to various individual problems, learning dis-abilities, or other unforeseen disruptions, a student may not understand specific items.

Definition of Terms

The following are definitions of terms used in this study:

1. Introductory Chemistry The Introductory Chemistry course (ChemCom) is an STS course designed for students who are not planning to major in a science-oriented field after high school graduation.

2. General Chemistry. The General Chemistry course (GenChem), taught with the traditional lecture/laboratory/ problem-solving curriculum, is designed for students with goals related to science theory or a science-related vocation after high school graduation.

3. Reasoning gain. Reasoning gain is described as any increase in reasoning ability as measured by the GALT posttest.

4. Reasoning mode. Reasoning modes include one concrete reasoning mode (conservation) and five formal reasoning modes (proportional reasoning, controlling variables, probabilistic reasoning, correlational reasoning, and combinatorial reasoning).

5. Science/Technology/Society Curricula. STS curricula describe curricula that encompass a science theme that is directly related to everyday experiences and decisions made by the general public. The ChemCom series is designed as a STS course.

6. Traditional Chemistry Curricula. Traditional chemistry curricula describe curricula that follow a lecture/ laboratory/problem-solving format relating primarily to theory and mathematics based science, such as the curriculum used in general chemistry.

ChemCom Curriculum Design and Relation to Teaching Strategy

The ChemCom curriculum is a year-long course built around eight societal issues related to chemistry (Nelson, 1988). These issues include water quality and supply, use and conservation of resources, the use of petroleum as both a fuel and chemical feed-stock, the chemistry of food and nutrition, nuclear chemistry, air and climate, chemistry and health, and the role of the chemical industry in our society (1988). The

ChemCom course includes less math overall than the traditional course, while still covering the major concepts, basic vocabulay, and lab-oratory skills expected in any traditional course (Nelson, 1988). It also presents more organic and nuclear chemistry than trad-itional courses. Each unit is laboratory-oriented and contains decision-making activities to give students practice in using chemistry to solve problems (Nelson, 1988). The ACS describes the objectives of the ChemCom course as follows: it helps students develop the skills necessary for problem-solving, such as the ability to identify problems; to consider and evaluate possible alternative solutions, weighing their risks and benefits; to separate facts from opinion; to verify information and evaluate the worth and objectivity of sources; to interpret quantitative information such as tables, charts, and graphs; and to formulate and reach decisions logically (Nelson, 1988).

It has been established that science teaching strategy and teaching process have a direct influence on student learning time, which in turn affects student achievement (Fisher et al., 1978; Roadrangka & Yeany, 1985). Teaching strategy types individually analyzed by Roadrangka and Yeany (1985) predicted 12% of the variance in student engagement, while the quality of teaching strategy predicted 35%. Overall, the type and quality of teaching strategy predicted 37% of the variance in student engagement (Roadrangka & Yeany, 1985). Most interestingly, these data indicated that the more indirect the strategy, the greater the student involvement in learning tasks (Roadrangka & Yeany, 1985).

Tobin (1980) identifies individual formal reasoning ability as a variable affecting student engagement and suggests that this variable be considered when teaching strategies are planned or when classroom research is conducted. Thus, the ability of teachers to use strategies that increase student engagement remains a critical factor. The teacher must employ strategies that consistently engage the students in learning tasks (Roadrangka & Yeany, 1985).

ChemCom covers these skills through a variety of student-centered, activity-based, issues-oriented chemistry curricula designed to encourage individual problem-solving and cooperative learning (Nelson, 1988). Teachers are provided with background information through regional and local inservice workshops that are funded by the National Science Foundation (Nelson, 1988). The exercises provided in the ChemCom curriculum generally fall into the following teaching strategies as identified by the Teaching Strategies Observation Differential (TSOD) (Anderson, James, & Struthers, 1974): indirect nonverbal, teacher planned open-ended investigations, and student planned investigations, the three strategies identified by Roadrangka and Yeany (1985) as most

conducive to student learning.

The text used for the general chemistry course is Chemistry by Addison-Wesley (Wilbraham, Stanley, Simpson, & Matta, 1990). An informal survey of teachers identified the most common teaching styles to be as follows: lecture, at least twice a week; labs, at least once a week; and problem-solving, at least once a week. Teachers for this course indicated that cooperative learning activities were used no more than once a month (D. A. Davison, D. Hawke, & A. J. Vandel, personal communication, September 1990).

Results of a study of teaching strategies and student formal reasoning level indicated that student formal reasoning ability predicted only 3% of the variance in time-on-task engagement and was not found to be a significant predictor of student engagement (Roadrangka & Yeany, 1985). Roadrangka and Yeany (1985) predict that quality of teaching does not make any difference in time-on-task between students who are formal thinkers and students who are not. Students at all levels of cognitive development should engage in learning if they are taught by high quality teaching (Roadrangka & Yeany, 1985).

Formal Reasoning Level of Adolescents and Science Achievement

Research has shown the prediction of formal reasoning level to be of vital importance for prediction of science achievement. Lawson (1983) investigated the hypothesis that student achievement is a function of the following cognitive variables: (a) repertoire of information processing schemata (i.e., Piagetian developmental level), (b) ability to disembed relevant information from irrelevant background (i.e., degree of field independence), (c) size of working memory (i.e., mental capacity), (d) prior relevant knowledge, and (e) prior relevant beliefs. Results of this study indicated that while prior knowledge is a good predictor of science achievement, the lack of the ability to disembed relevant information from irrelevant background is just as important in predicting student learning (Lawson, 1983). It was also found that mental capacity did not account for an appreciable amount of the variance in achievement in the overall course (Lawson, 1983). This study indicates the importance of a course structure that provides information for separating fact from popular fiction, as does the ChemCom series.

Five formal operational reasoning modes (Bitner, 1986, 1989, 1991; Capie, Newton, & Tobin, 1981; DeCarcer et al., 1978; Inhelder & Piaget, 1958; Lawson, 1983, 1985; Linn, 1982) and critical thinking skills (Bitner, 1991; Blosser, 1985; National Science Board Commission, 1983; Adler, cited in Bitner, 1991; Boyer, cited in Bitner, 1991) have been identified as essential abilities for success in advanced secondary school

science and mathematics courses. Bitner (1991) describes formal operational reasoning as advanced by Inhelder and Piaget as the structured whole which allows one to synthesize inversions and reciprocities in a unitary system of transformations. These five formal operational modes of reasoning consist of proportional reasoning, controlling variables, probabilistic reasoning, correlational reasoning, and combinatorial reasoning (Bitner, 1991). Inhelder and Piaget (1958) identify the approximate ages for acquisition of formal reasoning skills as 12-15 years of age.

Methods

The primary purpose of this study was to compare the influence of ChemCom versus GenChem curricular format on the acquisition of formal reasoning skills. The second purpose of this study was to determine gender differences in reasoning skills.

Presented are the methods and procedures followed in this study. The following items are detailed: hypotheses, population and sample, instrument, administration of the instrument, treatment, and statistical analysis procedure.

Hypotheses

The following null hypotheses were tested in this study:

HO_1 There is no significant difference in student gain in formal operational thinking in courses us the ChemCom approach versus the GenChem style.

HO_2 There is no significant difference in reasoning gains of students enrolled in GenChem versus ChemCom.

HO_3 There is no significant difference in reasoning abilities between males and females enrolled in GenChem and ChemCom.

Population and Sample

The sample ($\underline{N}$ = 123) for this study was chosen by randomly selecting classrooms from five high schools in a Midwestern city. GenChem ($\underline{n}$ = 60) was comprised of students enrolled in General

Chemistry, a course traditionally taught as a prerequisite for students pursuing a science-related vocation. ChemCom (n = 63) was comprised of students enrolled in Introductory Chemistry, a course designed for students interested in pursuing nonscience related vocations. Students receiving the posttest had success-fully completed both semesters of the course enrolled in, had not transferred class during the school year, and were not repeating the course. GenChem included 30 females and 30 males. ChemCom included 32 females and 31 males. The mean age, standard deviation and age range for subjects in each group are as follows: (a) GenChem, M = 15.83 years, SD = .77 years, Range = 14.9-17.92 years; (b) ChemCom, M = 15.93 years, SD = .85 years, and Range = 14.25-17.92 years.

Although students tested were from five different high schools, each high school in this public school district uses the same curricula for both courses. A Major Instructional Goal system is used throughout the school district, specifying the major objectives to be covered for each course. The same text-books are also used throughout the system.

<u>Instrument</u>

The Group Assessment of Logical Thinking (GALT) is a paper-and-pencil test described by Roadrangka et al. (1982) as follows:

1. The test measures six logical thinking operations: conservation, proportional reasoning, controlling variables, combinatorial reasoning, probabilistic reasoning, and correlational reasoning.

2. The test uses multiple choice format for presenting options for answers as well as the justification or reason for that answer.

3. Pictorial representations of real objects are employed in all test items.

4. The test is suitable for students reading at the sixth grade level or higher.

5. The test has sufficient reliability and validity to distinguish between groups of students at concrete, transitional, and formal stages of development.

6. The test can be administered in one class period to a large group by individuals who serve simply as proctors.

Research investigating the reliability of the GALT when compared to Piagetian interview tasks indicated a reliability of .85 (Roadrangka et

al., 1983). A (.80) correlation between the GALT and Piagetian interview tasks indicates concurrent validity (Roadrangka et al., 1983).

The abbreviated form of the GALT was used to determine student formal reasoning level prior to and after completion of the chemistry course in which enrolled. The pretest con- sisted of items 1 and 4 (conservation), 8 and 9 (proportion- ality), 11 and 13 (controlling variables), 15 and 16 (prob-ability), 17 and 18 (correlational), and 19 and 20 (combin- atorial). The posttest consisted of items 2 and 3 (conser- vation), 7 and 10 (proportionality), 12 and 14 (controlling variables), 15 and 16 (probability), 17 and 18 (correlational), and 19 and 21 (combinatorial). Students were classified according to reasoning level by the following scores: (a) 8-12, formal; (b) 5-7, transitional; and (c) 0-4, concrete.

Administration of the Instrument

The investigation began with the administration of the GALT pretest during the week of September 2-5, 1990. Students who completed the course successfully were given a posttest during the week of May 19-23, 1991. Tests were administered by the classroom teacher, each of whom received written and verbal instructions regarding proper administration of the test. Six classrooms of general chemistry students (GenChem) were randomly chosen for testing, while seven classrooms of Introductory Chemistry students (ChemCom) were chosen for testing. Only students that successfully completed the chemistry course in the same classroom were posttested. Data were not used for students who were repeating the course, who had changed schools or class- rooms during the year, who had been out of the classroom for more than 3 weeks, or who had failed one or both semesters.

Treatment

Developed by the American Chemical Society (ACS) with financial support from the National Science Foundation (NFS) and other ACS funding sources, ChemCom was written and field-tested by teams of high school, college, and university teachers, assisted by chemists from industry and government (Nelson, 1988). This year-long course was designed primarily for students pursuing nonscience careers. ChemCom includes the major concepts, basic vocabulary, and intellectual laboratory skills expected in any introductory chemistry course, while also incorporating a greater number and variety of student-oriented activities and laboratory exercises, many designed especially for the series (Nelson, 1988). In addition to these exercises, each unit contains three levels of decision-making activities and several types of problem-solving exercises designed to challenge the students'

intellectual thinking processes (Nelson, 1988).

There is no math prerequisite for enrollir.g in the ChemCom course in the sampled school district.

The textbook used for the general chemistry course (GenChem) was Chemistry, published by Addison-Wesley (Wilbraham et al., 1990). The text is designed as a theory-based reference for subjects traditionally studied in chemistry. Some specific units of the course include "Matter, Change, and Energy"; "Scientific Measurement"; "Problem Solving in Chemistry"; "Atomic Structure";
"Stoichiometry"; "States of Matter"; "Gases"; "Electrons"; "Periodicity"; "Bonding"; "Aqueous Systems"; "Solutions"; "Reaction Rates"; "Acids and Bases"; "Oxidation-Reduction and Electrochemistry"; "Metals and Nonmetals"; "Nuclear Chemistry"; "Hydrocarbons and Functional Groups"; and "Organic Reactions."

Students enrolling in the general chemistry course are required to have passed Algebra I averaging 75% or better. For each chapter in the Addisc..-Wesley Chemistry test (Wilbraham et al., 1990), two pages or less are related to applying the theories and/or principles being learned in that chapter to everyday occurrences.

Statistical Analysis of Data Procedures

Statistical programs in Statistics with Finesse (Bolding, 1985) were used to analyze data. The null hypotheses were tested at the .01 level of significance. Means and standard deviations were computed for the GALT pretest and posttest scores for both groups. An effort was made to adjust for any preexisting differences which may have been present between the two groups by using an analysis of covariance to determine any significant differences in mean GALT pretest and posttest scores between GenChem and ChemCom. To analyze differences in reasoning levels on the GALT pretest and posttest, a chi-square statistic was used.

Results

Student reasoning level was identified for both groups tested before and after treatment. Reasoning levels and gender differences between groups were identified and compared.

Included in the results section are the means and standard deviations for the pretest and posttest results for GenChem and ChemCom for each reasoning mode. The results of the analysis of covariance between GenChem and ChemCom and between gender on the GALT are presented. Also reported are the results of chi-square

statistics for GenChem and ChemCom reasoning level and for gender in reasoning level.

Descriptive Statistics for the GALT Pretest and Posttest

The means and standard deviations from least to most difficult per reasoning mode and total score on the abbreviated GALT pretest and posttest for GenChem (n = 60) were as follows: (a) conservation, pretest (M = 1.58, SD = 0.59), posttest, (M = 1.30, SD = 0.82); (b) combinatorial logic, pretest (M = 1.00, SD = 0.40), posttest (M = 1.33, SD = 0.74); (c) controlling variables, pretest (M = 1.00, SD = 0.77), posttest (M = 1.00, SD = 0.88); (d) proportional reasoning, pretest (M = 0.90, SD = 0.77), posttest (M = 0.48, SD = 0.67); (e) probabilistic reasoning, pretest (M = 1.00, SD = 0.88), posttest (M = 1.00, SD = 0.88); (f) correlational reasoning, pretest (M = 0.35, SD = 0.58), posttest (M = 0.48, SD = 0.60); and total score, pretest (M = 6.65, SD = 2.48), posttest (M = 6.68, SD = 2.43).

The means and standard deviations for ChemCom (n = 63) pretest and posttest are described as follows: (a) conservation, pretest (M = 1.30, SD = 0.82), posttest (M = 1.38, SD = 0.82); (b) combinatorial, pretest (M = 1.33, SD = 0.74), posttest (M = 1.54, SD = 0.59); (c) controlling variables, pretest (M = 0.68, SD = 0.67), posttest (M = 0.67, SD = 0.76); (d) proportional reasoning, pretest (M = 0.48, SD = 0.67), posttest (M = 0.78, SD = 0.73); (e) probabilistic reasoning, pretest (M = 0.33, SD = 0.70), posttest (M = 0.75, SD = 0.84); (f) correlational reasoning, pretest (M = 0.23, SD = 0.50), posttest (M = 0.46, SD = 0.62); and total, pretest (M = 4.32, SD = 2.31), posttest (M = 5.54, SD = 2.28).

The means and standard deviations for the total population are described as follows: (a) conservation, pretest (M = 1.44, SD = 0.77), posttest (M = 1.53, SD = 0.64); (b) combinatorial, pretest (M = 1.56, SD = 0.64), posttest (M = 1.54, SD = 0.55); (c) controlling variables, pretest (M = 0.84, SD = 0.73), post-test (M = 0.86, SD = 0.75); (d) proportional reasoning, pretest (M = 0.68, SD = 0.75), posttest (M = 0.86, SD = 0.75); (e) prob-abilistic reasoning, pretest (M = 0.66, SD = 0.86), posttest (M = 0.86, SD = 0.75); (f) correlational reasoning, pretest (M = 0.28, SD = 0.50), posttest (M = 0.46, SD = 0.62); and total, pretest (M = 5.46, SD = 2.26), posttest (M = 6.24, SD = 2.45).

Table 1.
Mean and Standard Deviation on the GALT for GenChem and ChemCom.

	Test Administration					
	Gen Chem Group 1		ChemCom Group 2		Total	
Reasoning Skill	M	SD	M	SD	M	SD
Conservation						
Pretest	1.58	0.59	1.30	0.82	1.44	0.77
Posttest	1.68	0.57	1.38	0.68	1.53	0.64
Proportionality						
Pretest	0.90	0.77	0.48	0.67	0.68	0.75
Posttest	0.95	0.77	0.78	0.73	0.86	0.75
Cont. Variables						
Pretest	1.00	0.76	0.62	0.67	0.84	0.73
Posttest	1.00	0.71	0.67	0.76	0.86	0.75
Probability						
Pretest	1.00	0.88	0.33	0.70	0.66	0.86
Posttest	1.33	0.84	0.75	0.84	0.86	0.75
Correlational						
Pretest	0.35	0.58	0.22	0.42	0.28	0.50
Posttest	0.48	0.60	0.43	0.64	0.46	0.62
Combinatorial						
Pretest	1.80	0.40	1.33	0.74	1.56	0.64
Posttest	1.55	0.50	1.54	0.59	1.54	0.55
GALT						
Pretest	6.65	2.48	4.32	2.31	5.46	2.26
Posttest	6.68	2.43	5.54	2.28	6.24	2.45

Hypothesis HO_1 and Results

The null hypothesis HO_1 proposed that there is no significant difference in student gain in formal operational thinking in courses using the ChemCom versus GenChem.

In Table 2, the frequencies and percentages according to reasoning levels for the GenChem GALT pretest and posttest were as follows: (a) pretest: 12 (20%) concrete operational; 24 (40%) transitional; and 24 (40%) formal operational; (b) posttest: 9 (15%) concrete operational; 24 (40%) transitional; and 27 (43%) formal operational.

The frequencies and percentages according to reasoning levels for the ChemCom GALT pretest and posttest were as follows: (a) pretest: 33 (52.38%) concrete operational; 24 (38.1%) transitional; and 6 (9.52%) formal operational; (b) posttest: 23 (36.51%) concrete operational; 27 (42.86%) transitional; and 13 (20.63%) formal operational.

Table 2

Level of Reasoning on the GALT Pretest and Posttest for GenChem and ChemCom
(GenChem _n_=60, ChemCom _n_=63, Total _N_=123).

	Reasoning Level					
	Formal [a]		Transitional [b]		Concrete [c]	
Group	N	%	N	%	N	%
GenChem						
Pretest	24	40.00	24	40.00	12	20.00
Posttest	27	43.30	24	40.00	9	15.00
ChemCom						
Pretest	6	9.52	24	38.10	33	52.51
Posttest	13	20.63	27	42.86	23	36.51

[a] Formal equals 8-12 score.

[b] Transitional equals 5-7 score.

[c] Concrete equals 0-4 score.

In Table 3 are reported the chi-square values for GenChem and ChemCom students at concrete operational, transitional, and formal operational reasoning levels. The number of students at the formal operational level in GenChem was significantly greater than ChemCom on the pretest, X2 (2, N = 123), 20.54, p<.0001, and on the posttest, X2 (2, N = 123), p<.0038.

These results support the rejection of hypothesis one, that there is no significant difference in student gain in reasoning level between groups.

Table 3

Chi-Square Values for GenChem and ChemCom Pretest and Posttest Scores.

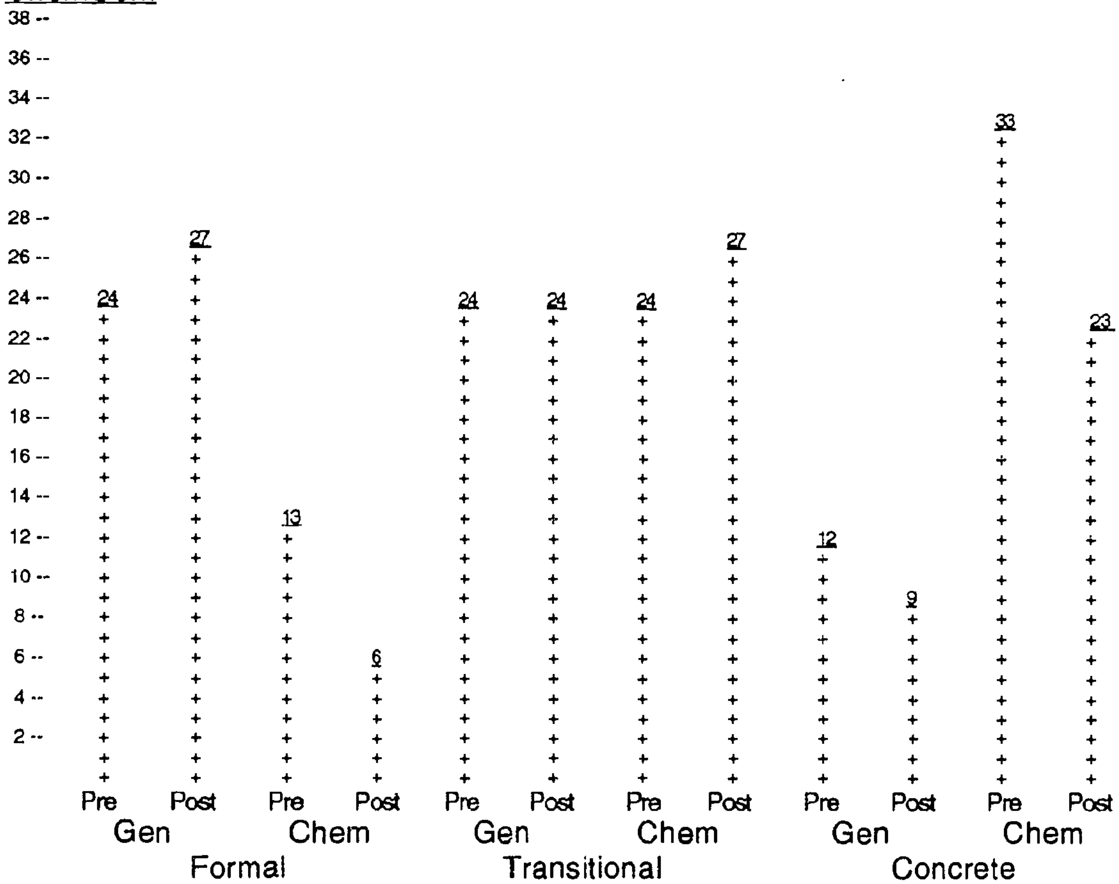
	X^2	Coef. of Cont.	df	p
Pretest	20.54	.38	2	.0001**
Posttest	11.13	.29	2	.0038*

* p<.01
** p<.0001

Figure 1 depicts a graph comparing reasoning gain on the GALT pretest and posttest scores for both groups. Chi-square statistics indicate a significant difference in reasoning gain between groups. The descriptive statistics indicate the following percentage gains between the two groups: (a) a 25.7% greater gain in formal reasoning for ChemCom versus GenChem; (b) a 5.9% greater gain in transitional reasoning for ChemCom versus GenChem; and (c) a 3.6% greater decrease in concrete operational reasoners in ChemCom versus GenChem.

Fig. 1

Graph Comparing Reasoning Gain on GALT Pretest and Posttest for GenChem and ChemCom



Hypothesis HO_2 and Results

The second null hypothesis states that there is no significant difference in reasoning levels of students enrolled in ChemCom when compared to students enrolled in GenChem. An analysis of covariance was used to analyze differences between groups of GALT pretest and posttest scores. In Table 4, the results of ANCOVA for the total GALT pretest and posttest scores indicate no significant difference $F(1, 118) = 119$, $p<.68$.

Table 4

ANCOVA for GenChem and ChemCom for GALT Pretest and Posttest Scores

Source	Adj. SS	df	Var. Est.	F	p
Between	.65	1	.63	.17	.68
Within	459.42	120	3.83		
Total	460.07	121			

Reported in Table 5 are the unadjusted and adjusted GALT pretest and posttest means for GenChem and ChemCom. These means indicate an average gain of .33 for students in GenChem and an average gain of 1.2 for students in ChemCom. The findings of the ANCOVA resulted in the acceptance of null hypothesis HO_2.

Table 5

Unadjusted and Adjusted GALT Pretest and Posttest Means for GenChem and ChemCom.

	GenChem		ChemCom	
	Unadj.	Adj.	Unadj.	Adj.
Pretest	6.65		4.32	
Posttest	6.98	6.33	5.54	6.16

Hypothesis HO_3 and Results

The third null hypothesis states that there is no significant difference in reasoning abilities between males and females.

In Table 6, the frequencies and percentages according to reasoning level for males were as follows: (a) pretest: 17 (27.8%) concrete operational; 24 (39.3%) transitional; and 20 (32.9%) formal operational; (b) posttest: 13 (21.0%) concrete operational; 24 (38.7%) transitional; and 25 (40.3%) formal operational.

The frequencies and percentages according to reasoning levels for females were as follows: (a) pretest: 22 (36.1%) concrete operational; 25 (40.9%) transitional; 14 (23.0%) formal operational; (b) posttest: 18 (29.1%) concrete operational; 26 (41.9%) transitional; and 18 (29.0%) formal operational.

Table 6

Level of Reasoning for Total GALT Scores and Gender

	Reasoning Level					
	Formal [a]		Transitional [b]		Concrete [c]	
Group	N	%	N	%	N	%
Males						
Pretest	20	32.9	24	39.3	17	27.8
Posttest	25	40.3	24	38.7	13	21.0
Females						
Pretest	14	23.0	25	40.9	22	36.1
Posttest	18	29.0	26	41.9	18	29.1

[a] Formal equals 8-12 score.

[b] Transitional equals 5-7 score.

[c] Concrete equals 0-4 score.

Table 7 reports the chi-square values for males and females performing at concrete operational, transitional, and formal operational reasoning levels. Chi-square values indicate that the difference in the number of males and females performing at higher reasoning levels was not si18gnificant with pretest values of X2(2, N = 123) = 1.01., p<.58, and posttest values of X2(2, N = 123) = .91, p<.63. The findings of the chi-square statistics support the acceptance of null hypothesis three. Gender differences were evident between the two groups.

Table 7

Chi-Square Values for Total GALT Scores and Gender

	X^2	Coef. of Cont.	df	p
Pretest	1.0810	.0933	2	.58*
Posttest	0.9115	.0860	2	.63*

* Not significant at .01.

Included in Table 8 are the results of the ANCOVA for the total GALT pretest and posttest for gender. The results of the ANCOVA indicated no significant difference, in reasoning gain, $F(1, 119) = 120$, $p<.37$.

Table 8

ANCOVA for Gender and GALT Totals

Source	Adj. SS	df	Var. Est.	F	p
Between	3.27	1	3.27	.86	.36*
Within	454.68	119	3.82		
Total	457.95	120			

* Not significant at .01.

Reported in Table 9 are the unadjusted and adjusted GALT pretest and posttest means for males and females. These means indicate an average gain of .85 for males and an average gain of 1.71 for females.

Table 9
Unadjusted and Adjusted GALT Pretest and Posttest Means for Gender

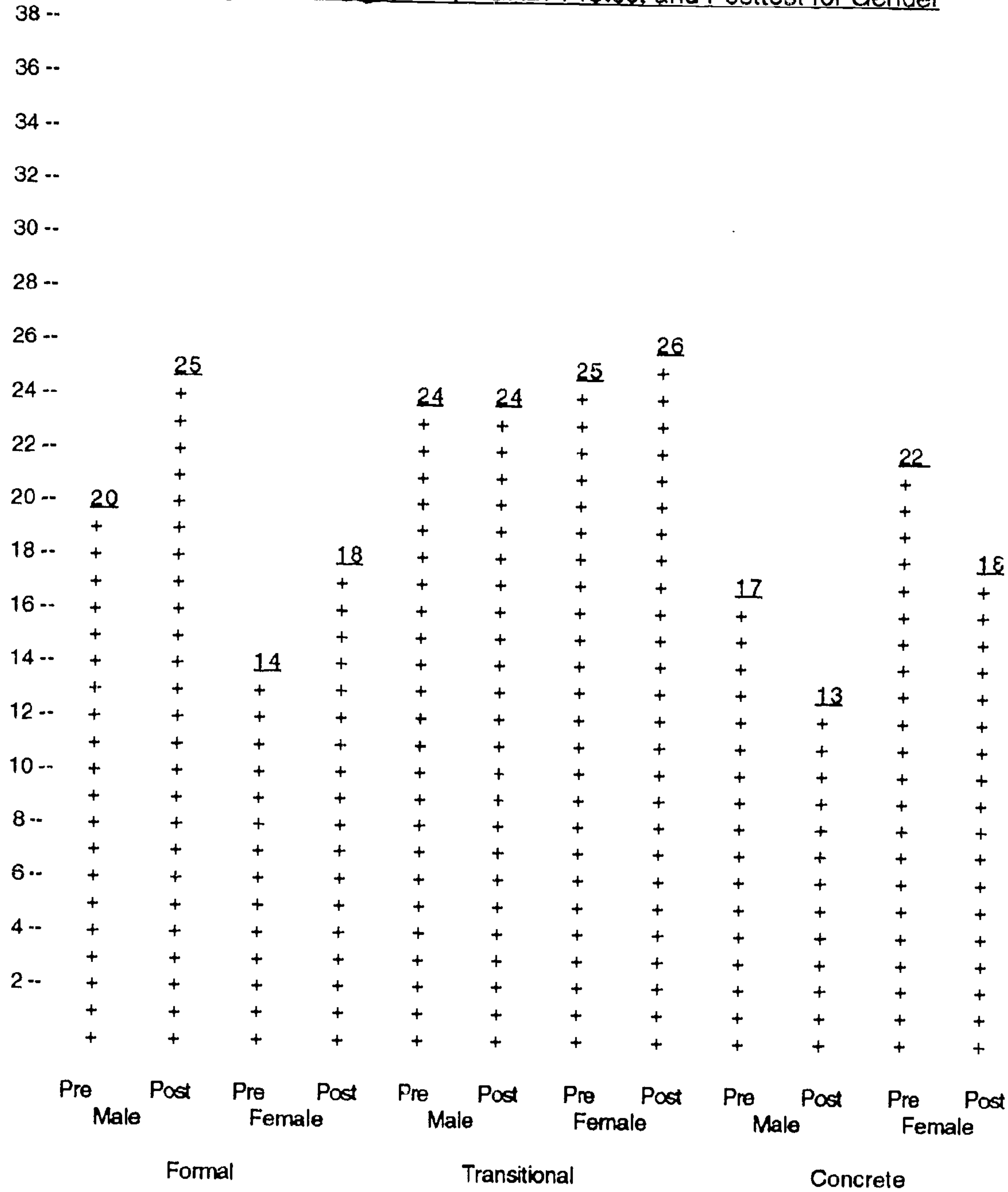
	Males		Females	
	Unadj.	Adj.	Unadj.	Adj.
Pretest	5.67		5.24	
Posttest	6.52	6.40	5.95	6.07

Figure 2 depicts a graph comparing reasoning gain on the GALT pretest and posttest for gender. The chi-square values indicate that no significant differences are evident in reasoning levels of males and females, but males scored higher on both the pretest and posttest.

Neither the chi-square statistic or the ANCOVA were significant. Therefore, hypothesis three was accepted, indicating no significant difference in reasoning level or reasoning gain for gender.

Fig. 2

Graph Comparing Reasoning Gain on GALT Pretest and Posttest for Gender



Summary, Conclusions, and Recommendations

The primary purpose of this study was to determine the influence of the curricular format on the acquisition of thinking skills. The secondary purpose was to determine gender differences in reasoning skills. Curricular influence was determined by comparing student reasoning gain as identified by the GALT pretest and posttest scores. Gender differences were identified by comparing GALT pretest and posttest scores of males and females.

A sample of 123 chemistry students was administered the 12-item abbreviated GALT pretest and posttest during the first week of school (pretest) and the next to the last week of school (posttest). GenChem (n = 60) received treatment in the form of a traditional lecture/laboratory/problem-solving format. ChemCom (n = 63) received treatment in the form of a STS curricular design.

Pretest and posttest GALT scores were statistically analyzed to evaluate reasoning gain and gender differences.

Conclusions

The following conclusions were drawn from this study:

1. There was no significant difference in reasoning gain of students in ChemCom versus GenChem, indicating that the teaching strategy did not make a significant impact upon student gain in reasoning skills.

2. A significant difference existed between students entering ChemCom versus GenChem.

3. Significant differences existed between males and females enrolled in both GenChem and ChemCom, and reasoning gains between males and females.

Discussion

The analysis of the data in this study indicates that no significant reasoning gain was observed between students enrolled in ChemCom versus GenChem at $p<.01$. Significant gains in reasoning were apparent in both groups, indicating that (a) exposure to techniques in both classes effectively promoted students reasoning gains; and/or (b) individual student maturation occurred, thus allowing individual students to better understand concepts requiring formal operational skills as the 9-month study progressed.

The reasoning mode that presented the most difficulty for students in both groups was correlational reasoning, followed by proportionality. This supports research conducted by Bitner (1986, 1989, 1991) which also identified correlational reasoning as the most difficult reasoning mode for middle and high school students.

Reasoning modes that presented the least difficulty for the total population (N = 123) were conservation and combinatorial logic. Both have been identified as concepts acquired during early stages of cognitive development (Inhelder & Piaget, 1958).

An interesting observation concerning 19.1% of the students identified as concrete operational reasoners on both the pretest and posttest, was that they did not attempt to answer the combinatorial question, "switches," on the last page of the posttest, even when many had answered the other combinatorial question correctly. A possible implication of this is that students did not attempt this question due to unfamiliarity with the subject matter, thus supporting research on content familiarity by Roadrangka and Yeany (1985).

Significant differences did not exist for gender. There was a greater number of males using formal operational reasoning as compared to females that enrolled in both courses. The difference in gain in formal operational thinkers between males and females was only 1.9%, implying that there was little difference in reasoning gain between gender. The total number of males at the formal operational level was slightly higher than females entering both courses.

Influence on the Validity of the Study

It is important to acknowledge that students in GenChem are often the more motivated, goal-oriented students while many of the ChemCom students are simply fulfilling high school science requirements. This could explain the greater number of students performing at the formal operational level on the pretest in GenChem versus ChemCom (24 in GenChem and 6 in ChemCom). GenChem would tend to draw more of the higher thinking students initially.

Implications

Although statistically, no significant gain was evident for students in ChemCom versus GenChem, ChemCom students did make a 25.7% greater gain in formal reasoning than students in GenChem. While this is statistically insignificant, educationally, the implications indicate that STS format may offer teachers a technique to encourage reasoning gain of students identified as concrete or transitional reasoners. By concentrating on a curriculum dealing with ontent familiarity and student focused activities, gains may be made with the concrete and transitional student.

No significant difference in gender was found in this study. This supports previous research by Bitner (1986, 1989, 1991) who did not

observe gender differences when investigating students in grades 6 through 10. A higher number of males entering chemistry had reached the formal level. An explanation for this could be that 38.3% of the males sampled had previously taken high school physics as compared to 12.6% of the females. The GALT items 1, 3, 4, 5, 9, 10, 11, 12, 13, 14, and 21 are questions that are similar to many test questions used in physical science and physics courses. This could have increased the content familiarity for a significant number of the males in the study. This question was not investigated.

Recommendations

Additional studies concerning the STS course designs are necessary. The following study suggestions are recommended:

1. A repeated test using a larger sample would increase the power of the findings.

2. A comparison of previous science courses taken and student reasoning level could provide insight on the effect of total science courses taken in relation to formal reasoning level.

3. A comparison of science courses previously taken by both males and females could help identify reasons for differences in reasoning level.

4. An investigation of student preference of curricula format and overall interest in an STS course compared to a traditional science course could provide insight into student motivation.

5. A long-term study of student formal reasoning gain in comparison to curricular format would increase the power of the findings.

6. A comparison of the number of and performance in math classes taken previously to the science course investigated could explain differences in formal operational reasoning gain.

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