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ABSTRACT

A comparison of CHEM Study and traditional chemistry classes showed no difference in student achievement in chemistry. The curricula did not have a differential effect on high vs. low ability groups. However, a difference in student attitude toward CHEM study and the traditional text, "Modern Chemistry," was observed. The students found CHEM study more difficult and less satisfying than the traditional curriculum. In this study, 33 CHEM study and 24 "Modern Chemistry" classes in the Rocky Mountain region of the United States were selected at random and given the following tests: Test on Achievement in Science, Science Process Inventory (SPI), Science Attitude Inventory (SAI), and Learning Environment Inventory. In addition, the teachers were administered the SAI and SPI. The statistical analysis of the test scores is described in detail. (BB)

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RESEARCH PAPER #4

A Comparison of CHEM Study Classes and Traditional Curriculum Classes with Respect to Achievement and Attitudinal Measures

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Prior to 1959, most of the new chemistry texts consisted of the core of knowledge from previous texts with a few new sections to cover the modern developments. No attempts were made to reorganize the material or to develop new approaches to it. Textbook publishers could not afford to gamble on something untried (Ridgeway, 1971).

In 1959 an American Chemical Society Committee recognized the need for an innovative approach to chemistry teaching and recommended that something drastic be done (Ridgeway, 1971). The National Science Foundation agreed to fund the research and in 1960 the Chemical Education Material Study (CHEMS) began under the chairmanship of Glenn Seaborg, freed from stifling financial considerations. For a total of three years, text and laboratory materials were tested, edited, and retested. Teacher training for the CHEMS course was implemented and in 1963 the hard cover edition was published for general use.

There have been many articles and studies written about different facets of CHEMS. They can be divided into two general categories: nonexperimental and quasi-experimental. The nonexperimental studies include general descriptions, historical documentation, subject matter comparison and philosophical evaluations. The quasi-experimental studies deal mainly with student achievement. They show essentially no differences between the CHEMS students and the traditional students in knowledge of chemistry (e.g., Rainey, 1964; Forchtner, 1968; Schaff and Westmeyer, 1970; Altendorf, 1965.) In Heath and Stickell's (1963) study, the CHEMS students tended to do better on the CHEMS exams while the traditional students tended to do better on the traditional exams. The differences were not significant.

In a recent study by Troxel (1970), however, significant differences were reported. He found students using CHEMS to perform significantly better than students using Modern Chemistry on (1) the American Chemistry Society Exam, (2) the Test on Understanding Science, and (3) the Watson-Glaser Critical Thinking Appraisal. Also, the students in CHEMS rated their chemistry class significantly higher on the Prouse Subject Preference Survey than the students in Modern Chemistry. This could support the suggestion of Forchtner (1968) that the CHEMS program provided a more relaxed, friendly classroom atmosphere. If the classroom atmosphere is indeed more relaxed and friendly, it is likely a student would prefer it.

In general, previous studies have had two major shortcomings: (1) the studies were quasi-experimental in nature, i.e., instead of randomly assigning treatments to selected classes, classes were selected so that all treatment groups were represented, and (2) analysis of data was done by using the student rather than the class as the basic statistical unit which can produce serious nonindependence problems and result in misleading conclusions (Glass, 1970). Although this study was also a quasi-experiment, three potential selection biases were statistically removed by using the three variables as covariates. The nonindependence problems were eliminated by using the class rather than the student as the basis for analysis.

This study investigated three questions: (1) Is there a difference in achievement between classes using CHEMS and classes using Modern Chemistry?

(2) Is there a difference in attitude between classes using CHEMS and classes using *Modern Chemistry*? (3) Do the curriculums have a differential effect on the ability groups? (e.g., possibly the high ability classes would do better with CHEMS while the diverse ability classes would do better with *Modern Chemistry*.)

Procedure

The data used in this study are a portion of the data collected as base line information for a National Science Foundation evaluation project (Welch and Gullickson, 1972). Chemistry classes in one geographical region of the United States were selected for testing. As Figure 1 illustrates, the region includes South Dakota, North Dakota, Minnesota*, Iowa, Nebraska, Wyoming, Colorado, Utah, Idaho, and Montana.

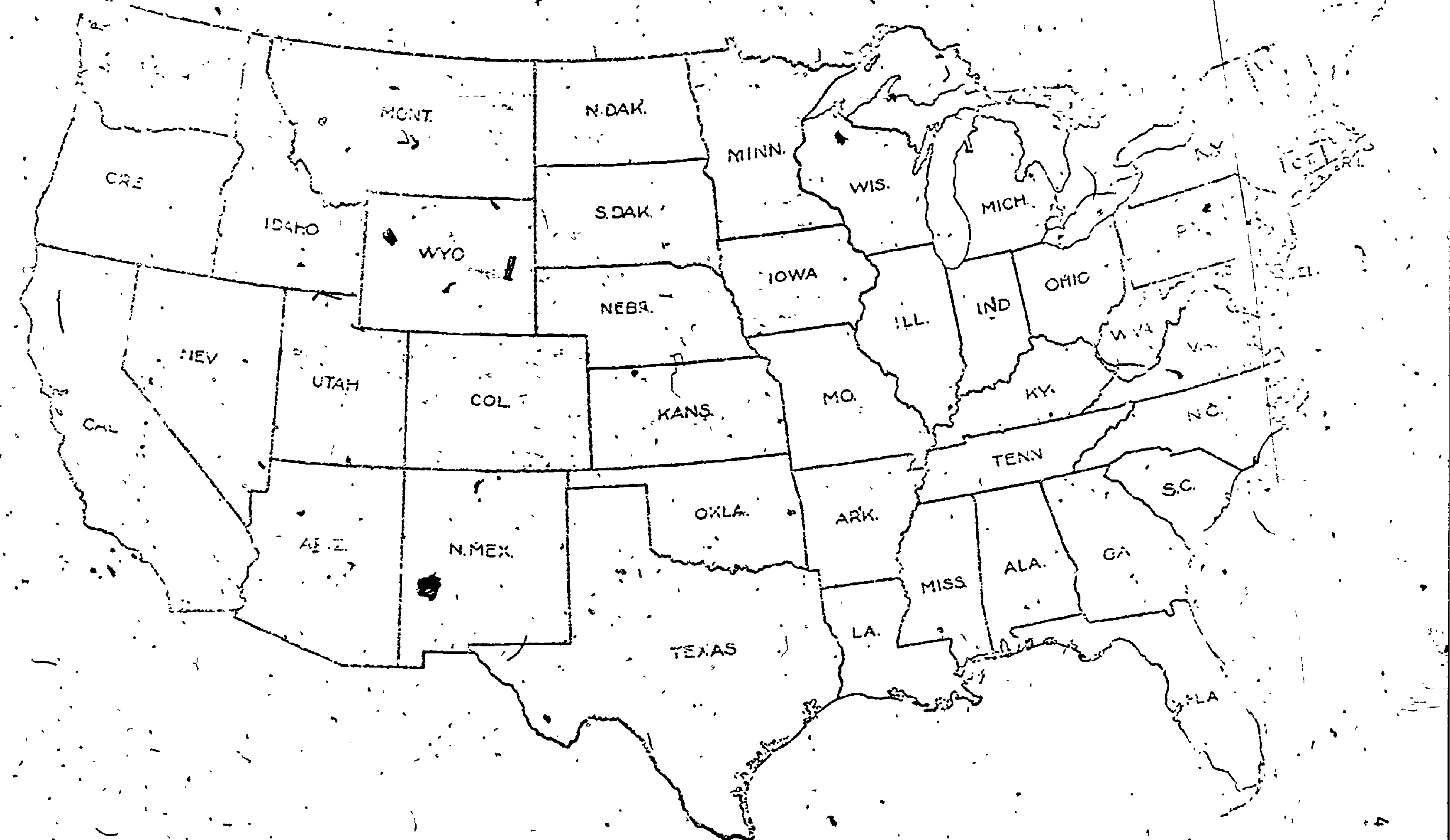
Insert Figure 1 about here

The population centers in these regions were stratified into three groups: (1) above 50,000, (2) 10,000 to 50,000, and (3) under 10,000. To insure that the sample was representative of the population distribution of the region, a percentage (population in strata per total region population) of the schools in each strata was selected. To select the sample, a list was made of all the schools in each strata, the list was entered randomly (using a table of random numbers), and the schools were selected systematically to obtain the desired percentage, e.g., every third school. The principal of each chosen school was asked to randomly select a chemistry teacher by drawing a name from a hat containing the names of all the chemistry teachers. That teacher was asked to

*Does not include Hennepin and Ramsey counties (Twin Cities and suburbs).

FIGURE 1

Region Sampled



complete a questionnaire, the Science Attitude Inventory (SAI) (Moore, 1967) and the Science Process Inventory (SPI) (Welch, 1966). In addition, the teacher administered four instruments to one randomly selected chemistry class. (All teachers were given specific instructions on how to select the class.) The four instruments were: (1) Test on Achievement in Science (TAS), (2) Science Process Inventory (SPI), (3) Science Attitude Inventory (SAI), and (4) Learning Environment Inventory (LEI) (Anderson, 1971). The instruments were completed in April of 1972.

The TAS is an instrument compiled from the items made available for public use from the National Assessment Education Project Test in Science for seventeen-year olds. The items selected do not involve the use of apparatus and were answered correctly by more than 5 percent but less than 90 percent of the students in the national assessment. There are 45 six-option items with a last option of "I don't know." The expected mean for any seventeen-year old is 22.4.

The SPI is a measure of understanding the processes of science. It consists of 135 items with either agree or disagree as a response. The SAI measures attitudes toward science. It contains 60 items each with the options: agree, strongly agree, disagree, and strongly disagree.

A modified version of the 15 scale LEI was used. It contains the 10 scales that showed maximum discrimination: (1) Diversity, (2) Formality, (3) Friction, (4) Goal Direction, (5) Favoritism, (6) Difficulty, (7) Democratic, (8) Cliqueness, (9) Satisfaction, and (10) Disorganization. Five of these scales were selected for this study: Diversity, Formality, Friction, Difficulty, and Satisfaction. It was felt that these scales would be more sensitive to the effect of a particular curriculum than the others. The LEI contains a total of 70 items each with the options: strongly agree, agree, disagree, and strongly disagree.

In order to complete the entire testing program in one class period, the class was divided into thirds with one-third taking the TAS, one-third taking the SPI, and the remaining third taking both the SAI and LEI. This division was accomplished by ordering the student instruments before the teacher received them so that as the teacher passed them out the first student would receive the TAS, the second student would receive the SPI, the third student would receive the LEI-SAI combination, and the fourth student would receive the TAS and so on.

The sampled classes were separated into two groups on the basis of what text the teacher said the class was using: (1) Chemistry, An Experimental Science and its revisions which are Chemistry, An Investigative Approach; Chemistry, Experiments and Principles; and Chemistry, Experimental Foundations; and (2) Modern Chemistry. These two groups contained a total of 57 classes of which 33 (57.9 percent) used CHEMS and 24 (42.1 percent) used Modern Chemistry. These two groups were then stratified by ability to provide a basis for the investigation of interaction. The teacher's opinion of whether the class's ability makeup was high, average or diversified was used as the measure of ability. As Table 1 shows these divisions provided a 2 x 3 factorial design with type of curriculum and class ability as the factors.

Insert Table 1 about here

The eight dependent variables were class mean scores on the SPI, TAS, SAI, and the five chosen LEI scales (see Table 2). The TAS and SPI scores were analyzed simultaneously by multivariate analysis of variance, and the remaining six attitudinal variables were analyzed univariately.

Insert Table 2 about here

TABLE 1

Number of Classes in Each Category of Curricula and Ability

Factors	High Ability	Average Ability	Diverse Ability	Totals
CHEM Study	12	14	7	33
Modern Chemistry	14	4	6	24
Totals	26	18	13	57

TABLE 2

Means and Standard Deviations of Class Means in Each Category of Curricula and Ability

Scale	High Ability CHEMS		High Ability Modern Chemistry		Average Ability CHEMS		Average Ability Modern Chemistry		Diverse CHEMS		Diverse Modern Chemistry	
	$\bar{X}$	sd	$\bar{X}$	sd	$\bar{X}$	sd	$\bar{X}$	sd	$\bar{X}$	sd	$\bar{X}$	sd
TAS	27.43	3.55	25.32	2.94	24.74	8.06	27.29	2.25	25.79	2.54	23.64	4.73
SPI	104.56	7.40	106.61	5.44	104.68	5.93	109.52	2.18	98.80	13.31	99.74	8.25
SAI	113.17	7.29	112.43	6.95	116.01	7.15	111.27	3.49	113.95	6.86	114.17	4.29
Diversity	2.83	.14	2.85	.08	2.84	.13	2.82	.18	2.90	.11	2.76	.08
Formality	2.61	.23	2.57	.20	2.68	.17	2.65	.20	2.66	.29	2.54	.25
Friction	2.14	.18	2.23	.21	2.21	.24	2.21	.11	2.15	.35	1.97	.39
Difficulty	2.97	.13	2.87	.17	2.98	.20	2.94	.15	3.03	.27	2.87	.21
Satisfaction	2.61	.34	2.69	.22	2.52	.26	2.68	.36	2.36	.30	2.80	.48

Analysis

The three variables chosen as covariates were: (1) teacher's knowledge of the processes of science as measured by the SPI, (2) teacher's attitude toward science as measured by the SAI, and (3) the size of the cities within which schools were located. Of those three only the teacher SPI scores contributed significantly. It had a significant effect on student SPI and SAI scores.

Of the three questions investigated, i.e., differences in curriculum, differences in ability, and the interaction of curriculum and ability, the knowledge and achievement variables (SPI and TAS) support a rejection of the null hypothesis ($p \leq .05$) only for differences in ability (see Table 3). (That difference was planned for via the teacher ratings and subsequent categorization before analysis.)

Insert Table 3 about here

Because the multivariate F value for ability difference was significant, the univariate F tests for ability on the TAS and SPI were reported in Table 4. The univariate F value for the student SPI scores was significant ($p \leq .01$), and Scheefé tests of the ability group means (see Table 5) showed that both the high and the average ability classes obtained significantly higher scores than the diverse ability classes. The lower score of the diverse group was expected because of the inclusion of low ability student scores in the class means.

Insert Tables 4 and 5 about here

Although the univariate F for the TAS scores was not significant at the .05 level, the combined means do show the expected trend of high ability classes obtaining the highest score followed by the average classes and finally the

TABLE 3

Multivariate F Tests

(TAS and SPI Scores)

Source of Variation	d.f.	F
Curriculum	2	.76
Ability	4	2.55*
Ability x Curriculum	4	.77

$^{*}p \leq .05$

TABLE 4

Univariate F Tests for Ability

Variable	MS	F
TAS score	19.42	.78
SPI score	255.05	4.82*

*$p \leq .01$

TABLE 5

Combined Ability Means for Student SPI Scores

Class Ability Level	N	SPI Score $\bar{X}$
High	26	105.9
Average	18	107.1
Diverse	13	99

diverse classes. This lends support to the opinion that ability differences do exist.

The three tests referring to curriculum, ability, and curriculum by ability interaction were done on each of the six attitudinal, dependent variables. As Table 6 shows, only two significant differences were obtained. Both were due to curriculum (CHEMS vs. Modern) and the significant differences ($p < .05$) occurred for the Difficulty and Satisfaction scales of the LEI. As reported in Table 7, CHEMS classes obtained the higher Difficulty score and Modern Chemistry classes obtained the higher Satisfaction score. These scores suggest that students perceive CHEMS as more difficult and less satisfying than Modern Chemistry.

Insert Tables 6 and 7 about here

Conclusions and Discussion of Results

As previously stated, this study had three main questions of interest. In answering the first question (Is there a difference in achievement between classes using CHEMS and classes using Modern Chemistry?), the results agreed with the bulk of studies done to date. There was no difference in student achievement in chemistry when taught by CHEMS or Modern Chemistry. That is, student achievement in chemistry was independent of which curriculum was used. Although this study did not provide answers to the general quality of either curriculum, the average TAS score for all of these classes as previously shown in Table 2 was above the National Assessment expected mean of 22.4. One would anticipate a higher average score because the expected score was computed for all seventeen-year olds regardless of their science background, while the students in this study were all chemistry students. However, it is encouraging

TABLE 6

Anova: Univariate F Tests

Source of Variation	d.f.	Diversity		Formality		Friction		Difficulty		Satisfaction		SAI	
		MS	F	MS	F	MS	F	MS	F	MS	F	MS	F
Curriculum	1	.007	.465	.05	.999	.011	.172	.131	3.8*	.499	5.36*	.0083	.0002
Ability	2	.0009	.06	.023	.46	.063	1.01	.009	.25	.047	.50	6.61	.17
Ability x Curriculum	2	.022	1.5	.01	.21	.043	.69	.0009	.025	.08	.87	47.89	1.21
Error	48	.015		.05		.062		.034		.093		39.68	

$^*p \le .057$

TABLE 7

Combined Text Means for Difficulty and Satisfaction Scores

Type of Curriculum	N	Difficulty	Satisfaction
CHEM Study	33	2.995	2.488
Modern Chemistry	24	2.894	2.726

to note that both curricula did increase the students' general knowledge of science.

Examining the second question (Is there a difference in attitude between classes using CHEMS or Modern Chemistry?) led to the conclusion that students perceive CHEMS as more difficult and less satisfying than Modern Chemistry. CHEMS provides a different approach to learning than most traditional high school classes. This "newness" could be causing the perception of difficulty rather than the actual course content. However, since the testing was done near the end of the school year, the student should be adjusted to the new approach. Also, since the CHEMS laboratory does not have any "right" answers, the students might not get as much of a feeling of satisfaction as the Modern Chemistry students who "prove" something they already know. The LEI scales of Formality and Friction did not show a significant difference, consequently, this study did not support Forchtner's (1968) view that CHEMS provides a more relaxed, friendly atmosphere.

None of the differences in the SAI mean scores were significant, but it is interesting to note that all of the class mean scores were above 112. This score is well above the neutral attitude score of 90. Apparently all the classes involved in this study had positive attitudes toward science.

According to the information obtained in this study, the answer to the third question (Do the curriculums have a differential effect on the ability groups?) is no. There was no significant interaction between curriculum and ability for any of the eight dependent variables. Therefore, there is no indication that one curriculum is better or worse for a particular type of class. This result is reassuring because it would probably be quite difficult for schools to provide different chemistry curricula for different ability level classes.

At the present time when much is being done to emphasize the new curriculum materials, e.g., CHEM Studies, it is somewhat reassuring to note that traditional courses such as Modern Chemistry are effective as well. Given the results of this study together with the results of the other studies mentioned, it seems appropriate to say that if a school is making a text adoption and is trying to decide between CHEMS and Modern Chemistry the decision is probably best made on factors other than expected student achievement, ability, or attitude. Variables such as teacher preference, knowledge and familiarity with the two curricula, and equipment and facilities available in the school would provide better information for the adoption decision.

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