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ABSTRACT

The goals of this four-phased study were to enhance the quality of educational experience for under-represented (rural, low income, and female) secondary students (N=628), and to increase their participation in mathematics and science courses beginning at the middle school level. Teachers (N=28) were asked to expand their pedagogical content knowledge, improve their student assessment techniques, and develop an integrated program linking mathematics and science to the core curriculum. During Phase 1, a consortium, organized by school districts, Southwest Missouri State University, and area business partners was established. During Phase 2, teams of teachers and consortium staff developed a 4-week interdisciplinary unit titled "PATTERNS." The project was implemented in Phase 3 and the project's effects on students and teachers were evaluated in the final phase. Results indicated: (1) teachers were generally pleased with the unified, consortium process; (2) analysis of pre- and post-test scores suggested that integrated approaches to teaching and learning that focus on formal operations are best suited to young adolescent learners who already possess some higher order thinking skills; and (3) students expressed interest and excitement in the unit. Some suggestions for further research, a teacher questionnaire, and six statistical tables complete the document. (LL)

PATTERNS: A Study of the Effects of Integrated Curricula on Young Adolescent Problem-Solving Ability

by

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EXECUTIVE SUMMARY

Funds f.r this project were provided by the Higher Education Competitive Grants Program of th Eisenhower Mathematics and Science Education Act administered by the Missouri Coorc nating Board for Higher Education.

This report describes a four-phased project designed to enhance the quality of mathematics and science education for under-represented students. During Phase I a consortium was formed. Organized by six southwest Missouri school districts, SMSU, and area business partners, this group set the staff and curriculum development agenda necessary to accomplish the project's goals.

In Phase II teams of teachers met with Consortium staff over a period of seven months to develop a four-week interdisciplinary unit titled PATTERNS. This unit focused on four themes: (a) Patterns exist in nature and are constructed by people. (b) Patterns help us recognize relationships and organize or classify related things. (c) Patterns help us analyze new things and/or new information. (d) Patterns can be used to solve problems.

Implementation of the PATTERNS unit took place in Phase III. Six hundred twenty-eight students in four different districts were taught the unit by six interdisciplinary teams of teachers, beginning in April, 1993. In all, twenty-eight teachers were involved in the implementation phase.

Phase IV consisted of an evaluation of the effects of the project on teachers and students. In sum, teachers were generally pleased with the unified, consortium process used to develop integrated curricula. However, they noted that a common planning time is vital and greater ownership could have been achieved if each team could have developed its own unit. Observational data would tend to indicate a relationship between ownership in the curriculum and level of compliance.

Students expressed interest and excitement in the unit, viewing the activities as fun and not routine. Residual analyses of the pre- / post-test scores produced data indicating that students identified as incipient formal operational thinkers made significant gains in their problem-solving ability.

Data from this study indicate that integrated approaches to teaching and learning that focus on formal operations are best suited to young adolescent learners who already possess some higher order thinking skills. As a result of this study, three questions in need of further examination are posited: (a) What types of integrated processes best facilitate student learning? (b) What learning styles are best suited for integrated approaches to problem solving? (c) Can formal operational thinkers improve their problem solving ability better through integrated approaches?

Background

Phase I -- Organization

In September 1992, the Southwest Missouri Regional Consortium was established. Sixty-three teachers, administrators, and SMSU faculty attended the organizational meeting at Pleasant View Middle school. The Consortium agreed to the following goals: (1) to create a curriculum information and dissemination network, (2) to provide professional development opportunities relating to interdisciplinary approaches to teaching mathematics and science with other "core" subjects, and (3) to develop integrated curricula and instructional methods (i.e., an interdisciplinary thematic unit) based on mathematics and science frameworks, and (4) to implement this unit and evaluate its effects on student cognitive and affective learning.

The Consortium targeted under-represented, rural southwest Missouri school children, especially low income and female students who might otherwise not participate in mathematics- and science-related endeavors. The integrated curricular materials developed by the Consortium were designed to engage this target group through active participation. Such participation demonstrated the "interconnectedness" of mathematics to science and its relevancy to other areas of learning, careers and life.

The overall goal was to enhance the quality of educational experiences for under-represented students and to increase their participation in mathematics and science education courses beginning at the middle school and continuing through high school and college, leading to life-long interest and participation in mathematics-based and science-based pursuits. To effect this change, teachers were asked to expand their content knowledge, pedagogical contend knowledge, and their techniques of assessing student performance. Teachers were also asked to develop an integrated program linking mathematics and science to the core curriculum, involving language arts, history/social studies, and other curricula with co-curricular and exploratory programs and activities.

In addition, teachers learned to establish vertical and horizontal articulation opportunities for the under-represented student cohort within and among all middle level school programs -- bridging the gap between elementary and high school, paying specific attention to the roles mathematics and science play in the process.

Phase II -- Staff & Curriculum Development

Shortly after the organizational meeting, the Project Investigator began holding a series of meetings at each participating school site. The purpose of these meetings was to establish teaching teams that would develop and implement an integrated unit. It was determined that the Project Investigator should work with these teams individually at each school site rather than have the teams attend a series of committee meetings.

Consortium staff consisting of a graduate assistant and three undergraduate students built a knowledge-base centered around integrated approaches to mathematics and science education. This knowledge-base included information gained through careful aggregation of materials compiled by the Consortium staff and members of the teaching teams. This knowledge-base was written in narrative form and disseminated to all participants under the title "Interdisciplinary Teaching: A Review of the Literature."

Teaching Teams worked collaboratively with Consortium Team members to develop, field test, and evaluate newly-created lessons, units, and instructional methods. From these teams Teacher Leaders were trained to facilitate subsequent curriculum and staff development. These processes were designed to help teachers integrate mathematics and science while providing linkages to the total school program and to demonstrate the relevancy of math/science to other academic areas and pursuits, in an effort to create a live-long interest and enthusiasm in under-represented youth in rural southwest Missouri.

Teachers developed a list of possible topics to be developed into integrated curricula. A problem-solving unit was chosen and subsequently titled PATTERNS. During the series of team meeting from October 1992 to January 1993, teachers brainstormed activities, collected materials, and met with Consortium Staff to develop the curriculum. The product evolved into a four-week interdisciplinary unit for grades 6, 7, and 8.

Throughout the development phase of this project, Consortium Staff consulted with University faculty and educators from a number of other universities, middle level schools, and business / community sponsors. These consultations helped to produce a network of individuals/organizations with experiences relating to integrated approaches to teaching math/science along with other school subjects.

Phase III -- Implementation

After the PATTERNS unit was written, and materials were procured, participating teachers, schools, and districts were asked to implement the unit. Table 1 shows the four sites that implemented the unit, along with the dates of implementation and the number of students at each grade level to whom the unit was taught.

Per human subjects review procedures, letters of "informed consent" were distributed to the parents / guardians of all students who, initially, might have been involved in the project. Two such letters indicated non-participation. All others agreed to take part in the study, producing an initial total student cohort of 628.

Two schools organized teachers into teams of four each. One school developed a team of five teachers. The fourth school involved 15 teachers on three separate teams. The total number of teachers involved across the four schools that implemented the unit was 28.

Table 1

Implementation Sites / Experimental Group Sample

School	Number of Teachers	Implementation Dates (1993)	Number of Students --by Grade-Level 6th	7th	8th	Totals
W	5	4/19-5/14	71	0	0	71
X	4	5/03-5/28	40	40	47	127
Y	15	5/17-6/11	100	145	115	360
Z	4	5/06-6/05	35*	35*	0	70
Totals	28	4/19-6/11	246	220	162	628

* Note: This school has 170 6th-graders and 140 7th-graders. While some number of students at each of these grade levels may receive some portion of the PATTERNS unit, it is expected that only 35 students at each level will receive the full program. This is due to the fact that the teaching teams do not share a common group of students.

Phase IV -- Evaluation

This self-evaluation necessarily requires careful analysis. Therefore, while self-report mechanisms and observations will constituted the primary effort, the last four months of the project -- September, October, November, and December (1993) -- were devoted to final data collection and analyses. This work was be performed by the Project Investigator and a research assistant.

Methods. The Consortium's plan of operation was built around mixed organizational and research methodologies. Qualitative case study work was essential to identify the patterns of relationships that shape critical features of mathematics/science curricula operational in middle level programs and practices and to generate different types of organizational cultures. Qualitative interviews and observation-based case studies were used to elicit practioners' views of schools and the factors that shape novel, integrative mathematics/science curricula at the middle school level. T-tests were performed to determine significant differences between pre- and post-test means, and a residual analysis of the pre- / post-test effect scores was performed. Content analyses were performed on the open-ended survey data for both students and teacher responses.

Results. Originally, three organizational groups were to be formed: (1) one Consortium Team, (2) several Teaching Teams, and (3) a number of Teacher Leaders. The Consortium Team was formed and consisted of the following individuals -- The Project Investigator (Dr. David Hough, Assistant Professor of Education; four SMSU faculty from the Departments of Curriculum Instruction and Mathematics; one public school teacher and graduate assistant (Ms Barbara St. Clair, seventh-grade science teacher, Reed's Spring Middle School; and three undergraduate middle school students. Other individuals from business and community organizations were consulted. Instead of meeting monthly, it was determined that this team should meet several times a week and travel to participating schools, rather than have school personnel travel to a central location. It was further agreed that the Consortium Team could solicit input from resource personnel on an "as needed" basis, rather than on a specified schedule. This process worked effectively and efficiently.

Teaching Teams consisted of four or more public school teachers in the same school. Teacher Leaders were identified from these teams. Teams were expected to meet daily during common planning times and work with Consortium staff to engage in the curriculum and staff development detailed in this proposal. Only one site was able to do this. All others met on a less systematic basis and usually before or after school.

All Teaching Teams were trained to (1) develop new and innovative mathematics / science curricula, integrating other core / co-curricular / exploratory areas and (2) train other teachers in the new curricula and instructional methods. Twelve teachers at one site met the requirements necessary to assume responsibilities commensurate with the role of teacher leader -- organizing, facilitating, and implementing prototypical multi- / interdisciplinary lessons with teams of teachers.

Effect on teachers. While the strength of qualitative field studies lies in their ability to capture internal organizational processes and contextual nuance, they are less effective in capturing reliable and stable patterns of organization and social relationships. Quantitative analysis is needed to identify regularities and frequencies of various contextual factors. Both qualitative and quantitative survey and file data provided an important means for evaluating instructional methods and integrated curriculum content.

Data from a survey questionnaire (see page 6) were combined with interview data gathered from the participants in a series of focus group sessions held between September 1, 1993, and October 31, 1993. Figure 1 displays the mean scores on the first three questions. Using a Likert-type scale ranging from 0 = Never to 5 = always, teachers agreed that the project provided them with opportunities to work as part of a team, $\underline{M}$ = 3.6. The unit enabled teachers to integrate math and science with other areas of study, $\underline{M}$ = 3.8. Most teachers believed that the interdisciplinary approach was beneficial for their students, $\underline{M}$ = 4.36. The grand mean was 3.95, indicating a general agreement that the project met the goals established by the consortium one year prior. In addition, teachers provided the following comments:

BENEFITS:

Students enjoyed Activities with no Test/quiz.
FOR THE STUDENTS & TEACHERS TO UNDERSTAND THE INTERDISCIPLINARY APPROACH OF TEACHING
Teachers communicating about elements common to different curricula.
High Interest Level
showing students how all subject can relate to one specific topic and how important each subject is to the student.
Enjoyed labs-
My students enjoyed the book of Three. I felt it was beneficial in encouraging them to read on their own and find patterns while reading.
It started in Math/Sci. and the other disciplines worked off of Math/Sci.-It seems to be the-other-way-around usually!
The most beneficial aspect of the Patterns unit was the opportunity to work in an interdisciplinary team and have my students see connections in their learning.
-the entire school was engulfed in the unit -it was well organized
Hands on projects

Suggestions for improvement.

Need to provide common planning time for teachers involved
More flexible time structure
Patterns must interject more background material and creative ways of measuring students understanding. Kids did not care for the deer activity. Not enough science facts/laws were involved.
More organization from day to day.Like what they weigh in Sci. should be done immediately following the Est. in Math-coordinate teacher Plans.
-Begin the PATTERNS unit during the first semester of school.
MAKE SURE ALL MATERIALS ARE SUPPLIED
Provide all materials needed for unit.
More teamwork would have occurred if we would of all had the same planning period.

Teacher Survey Questionnaire

Using Mathematics and Science to Integrate School Programs: A Regional Staff and Curriculum Development Consortium

(For questions 1, 2, and 3, please use the scale provided and circle your response.)

		Always		Somewhat		Never	
1.	This project provided me with the opportunity to work with a team of teachers.	5	4	3	2	1	0

Comments:

2.	The PATTERNS unit enabled me to integrate math and science with other areas of study.	5	4	3	2	1	0

Comments:

3.	The interdisciplinary approach used was beneficial to my students.	5	4	3	2	1	0

Comments:

4. What were the most beneficial aspects of the project and/or PATTERNS unit?

5. What suggestions do you have for improving the project and/or PATTERNS unit?

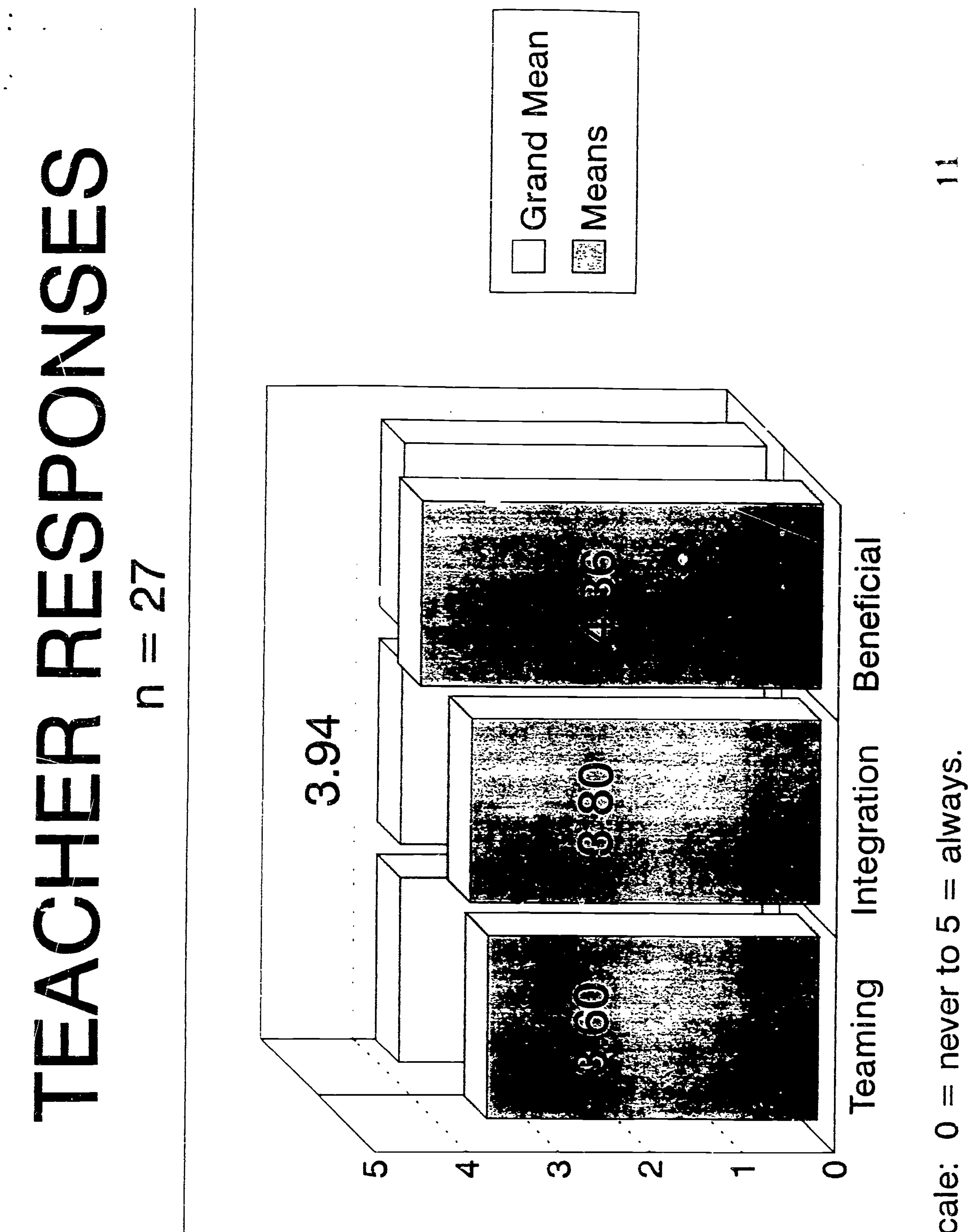

Figure 1. Mean scores on teacher response survey questionnaire.

Effect on Students. Initially, a total of 628 students were involved in the project (see Table 1). Of these, 459 were actually taught the four-week interdisciplinary unit titled PATTERNS. As Table 2 indicates, this sample group consisted of 161 6th-graders from three different schools, 238 7th-graders from three different schools and 60 8th-graders from the same school. Two hundred twenty-eight students were female and 231 were male. Two schools were located in urban areas and two were located in rural areas.

Table 2

Sample group by school, grade level, and gender.

School	Number of Students per Grade Level			Gender		Number of Students per School
	6th	7th	8th	F	M	
A	68			31	37	68
B	17	34		20	31	51
C		104		50	54	104
D	76	100	60	127	109	236
Totals	161	238	60	228	231	459

A field test was used to determine the appropriateness of the Group Assessment of Logical Thinking (GALT) for measuring the problem-solving skills of middle level students. The GALT was administered in December, 1992, to 45 sixth-grade students in a southwest Missouri school. The students were selected because of their availability and similar demographic make-up as compared to the study's subjects.

Results showed that the test was too difficult to discriminate among sixth-grade students: (a) the average total score for the 45 students was 4.6 out of 20 possible; and (b) 15 items were answered correctly by fewer than 10 students.

Additional items measuring lower-level concrete thinking skills were selected from Piagetian-style tasks described by Bybee and Sund (1982). The GALT items and the Bybee and Sund items then served as templates for questions developed by the researcher so that each cognitive skill would have two parallel questions. Padilla and Bybee granted permission by telephone to use their test items.

Parallel tests of 20 problems each were developed and pilot tested on 94 seventh-grade Reeds Spring students (47 students per test half). Item difficulty was evaluated by totalling the number of correct and incorrect responses per item. Item discrimination was evaluated by examining the range of total scores.

Based on item difficulty, two equivalent tests were constructed by selecting questions that totaled equal numbers of correct and incorrect responses. These two comparable, equally-weighted tests were then used as a pre-test and post-test.

Students participating in the study were given a pretest and posttest with a pencil-and-paper, multiple-choice instrument developed to measure problem solving. The decision was made to define problem solving by some of its operational processes and therefore to measure problem solving by evaluating those processes. The processes involved in problem solving include seriation, classification, conservation, proportional reasoning, controlling variables, probabilistic reasoning, combinatorial reasoning, and correlational reasoning.

Each item on the test presents an experiment or problem. Sufficient information is provided to allow the student to answer the question without additional content knowledge. Pictorial representations are included to clarify the questions and reading level is appropriate to fifth or sixth grades. In addition to selecting the correct answer to the item question, students are required to select the correct reason for their choice. Both answer and reason must be correct for the student to receive credit for the item. These test design factors decrease the possibility that a student will score correctly on any item by chance and increase the likelihood that the item measures process.

Table 3 shows the pre-test and post-test results by school. The t-test used to determine the level of significance for the difference between these two tests indicate that the pre- and post-test means for school Y were significantly different. However, because a control group was not used, an analysis of the residual effects is a more appropriate statistical procedure. This residual analysis is shown in Table 4 and indicates that a sub-population of students may have benefitted from the unit.

Table 3

T-scores for pre- and post-test means.

School	Number of Students	Pre-Test Mean	Post-Test Mean	Effect Gain	T	P
W	68	8.64	8.91	+.26	- .95	.345
X	104	9.77	10.09	+.31	-1.07	.285
Y	236	10.54	9.45	-1.08	4.76	.000
Z	51	8.54	7.86	- .68	1.91	.062
Total	459	9.86	9.34	- .52	3.50	.001

Table 4.

Crosstabs residual analysis of pre-/post-test gain scores. (N=449).

	Post-test				
Pre-test	0-5	6-10	11-15	16-20	Totals
0-5	16	17	1	0	34
6-10	56	126	33	11	226
11-15	5	56	98	16	175
16-20	1	2	5	6	14
Totals	78	201	137	33	449

X^2 (361) = 443, p = .002.

Table 5 shows pre- and post-test means, differences, standard deviations and T scores for all the sub-populations of students who had gains on the post-test. Residual analysis of these data suggest that significant gains were made by 28 students who scored 16 or higher on the post-test. The effect gain for this cohort is .55 (p = .001). Figure 2 shows the frequency distributions for both pre- and post-tests, presented as line graphs.

Table 5.

T scores on pre- and post-test mean differences, per subpopulations of post-tests.

Post-test Scores	N	Post M	Pre M	Diff.	SD	T
17-19	**13**	**17.46**	**14.38**	**3.07**	**2.39**	**4.63[a]**
16-19	**28**	**16.67**	**13.32**	**3.35**	**2.80**	**6.33**
15-19	41	16.14	13.36	2.78	3.08	5.77
14-19	61	15.44	12.98	2.46	3.18	6.04
13-19	90	14.65	12.53	2.12	2.83	7.11
12-19	129	13.85	12.15	1.69	2.64	7.30
11-19	170	13.16	11.86	1.99	[illegible].58	6.57
10-19	220	12.44	11.45	.99	2.58	5.68
9-19	273	11.77	11.06	.71	2.60	4.54
8-19	319	11.23	10.73	.49	2.64	3.33[a]
7-19	349	10.86	10.53	.33	2.68	2.33[b]

Levels of significance: [a](p = .001); [b](p = .020); all others (p < .0001).
Bolded scores represent the sub-populations with significant effect gain scores; Group (n = 13) effect gain .68 (p = .001); Group (n = 28), effect gain .55 (p = .001). Average effect gain of the two groups is .62.

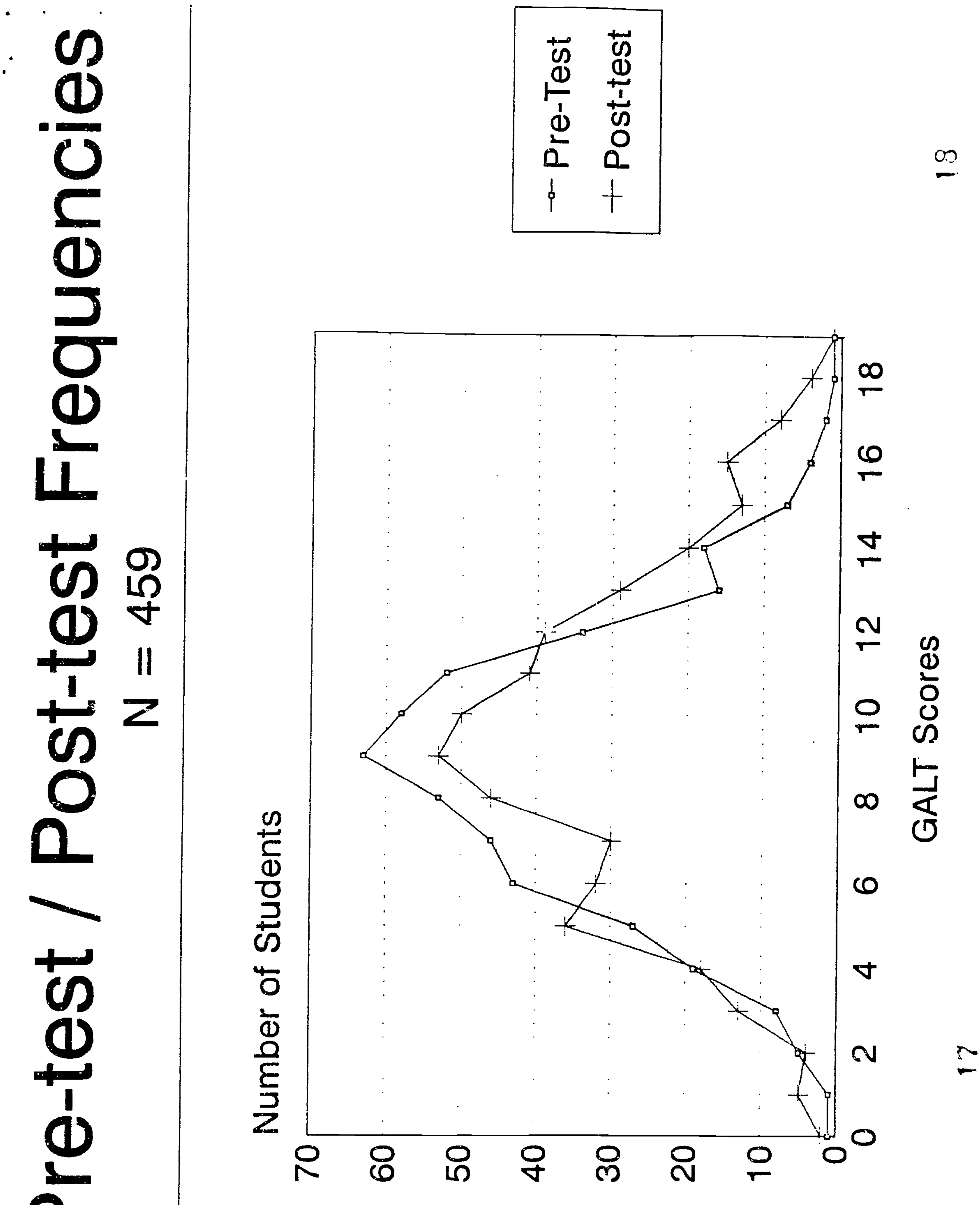

Figure 2. Pre- / Post-test Frequencies.

The final phase of evaluation on the effects of interdisciplinary curriculum and instruction on students involved the affective domain. Students were given an open-ended questionnaire consisting of five questions. Table 6 summarizes the results of this questionnaire.

Table 6.

Rank Ordered Results of Students Evaluations (N = 459) and (Number) in Agreement.

Rank	Number	Activity Most Enjoyed
1	36	Fibonacci's spiral
2	26	The games
3	23	Math patterns
4	22	The popcorn experiment
4	22	Making cities
5	18	Science patterns
6	17	Reading The Book of Three
6	17	Doing experiments
7	11	Sea shells
7	11	Graphing
8	10	Making a blueprint of my room
9	9	Sampling
10	5	Making maps
11	4	Finding patterns in the halls
11	4	No textbooks
11	4	Pattern pages in math
11	4	Zoning
12	3	Getting into groups
12	3	Studying Branson
13	1	Measuring volume of marbles
13	1	Making and giving surveys
13	1	Making a patterns folder
13	1	Weighing things in math

Rank	Number	Activity Least Enjoyed
1	8	Reading The Book of Three
1	8	Sea Shells
2	7	The tests
3	6	Graphs in Social Studies
4	4	Worksheets
5	3	Poems
5	3	The things in science class
6	2	The measuring part (it took to long)
7	1	Alphabetizing
7	1	Not doing patterns in Reading
7	1	Writing so much information down

Rank	Number	Significance of Unit
1	38	To learn that there are thousands of patterns in the world.
2	35	To learn patterns
3	15	Because they had to
3	15	To learn how to solve problems
4	14	They wanted us to know how things relate in all classes.
5	10	They want you to know how to put subjects together.
6	5	They wanted us to do something neat and learn in a different way.
7	3	Because the person from SMS picked our school
7	3	That school can be fun
7	3	They wanted us to learn more, that sw use patterns and we didn't even know it.

Rank	Number	Difference From Traditional Instruction
1	18	The PATTERNS unit was more fun
2	9	I like having it tie in with all subjects
3	8	We didn't have lots of homework
4	6	We got to work with our friends
5	5	Well, playing games was different and most of the teachers kept saying now do you see the patterns in this, otherwise it was the same
6	4	We usually do a lot more work
6	4	We didn't work out of the book
7	1	We did more stuff out of the classroom
7	1	We had science in math
7	1	I actually learned something. The stuff we used to do was really boring but Patterns were a lot of fun

Rank	Number	Suggestions for Improvement
1	75	No, but I liked it!
2	8	I just wish we could have it longer than we did! It was great.
3	7	More experiments
3	7	More map-making
4	3	Don't do so much writing work
5	2	Get more funny, creative worksheets for math
5	2	It is too long. I think almost everyone was getting sick of it, even teachers
5	2	Do not read The Book of Three
6	1	I think the 4 week unit was pretty fun and easy for most 6th graders