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Differences in Creativity Developed by Students in STS Sections Compared to Those Taught by the Same Teachers in Textbook Sections

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ABSTRACT *The Iowa Chautauqua Program has operated in Iowa since 1983, involving K-12 teachers across the state. One key feature has been the involvement of a lead teacher who mentored up to ten new teachers. Fifteen of the Lead Teachers agreed to participate in a research project designed to collect information concerning the effectiveness of a Science-Technology-Society (STS) approach to the development of selected creativity skills when compared with a textbook section. The results indicate that STS produces students who are significantly better in terms of number of questions raised, exploration offered and suggestions of ways to determine the accuracy of the exploration following experiences with discrepant events. Fewer unique questions and explanations were found from students enrolled in more traditional textbook sections.*

KEY WORDS: *Science-Technology-Society, creativity skills, discrepant events, questioning.*

Introduction

Torrance (1974) has described creativity as "a process of becoming sensitive to problems, deficiencies, gaps in knowledge, missing elements, disharmonies, when persons must identify the difficulties; search for solutions, make guesses, and/or formulate hypotheses about the deficiencies; test and retest these hypotheses and possibly modifying and retesting them again; and finally communicating the results to others" (p. 8). Interestingly, Torrance's description illustrates the relationship between creativity and science.

Creativity or creative thinking for this study is related to many aspects of science when confronted with discrepant events, including generating relevant and unique questions, identifying possible explanations, testing such ideas, and predicting probable effects or consequences of a given condition or event–either real or hypothesized. It includes communicating the results to others attempting to gain their concurrence that the evidence for the validity of the explanations is strong. It is like a detective looking for clues in an investigation and sharing the results. Science to be successful requires creativity for all the major aspects of the endeavor. The first goal for school science listed in the National Science Education Standards (NRC, 1996) indicates that science should produce students who experience the richness and excitement of knowing about and understanding the natural world. This occurs from natural curiosity and the use of the human brain in dealing with that curiosity – traits that all humans have. But, science demands doubting initial explanations offered to satisfy curiosity. It requires searching for evidence that the explanation has validity in terms of logic, experimentation, a collection of evidence to share with others. All of these activities exemplify and require creativity. Unfortunately, a focus on creativity and the acts that constitute it are not frequently found in typical science classrooms.

Science-Technology-Society (STS) has been a reform effort around the world since the 70's. Efforts in the U.K. attracted attention in the U.S. with many attempts in the science and social studies to organize the curriculum around real world problems and issues which could create situations where traditional context and skills would be found useful in contexts that were presumably relevant to students, tied to local areas, and other associations with current social issues and events. One of the major efforts for STS reformers has been to enhance creativity skills. Such enhancement has invited use of a constructivist learning theory; it has made STS synonymous with constructivism and inquiry.

Yager (1989) summarized the differences between STS and traditional textbook programs in terms of science education. The distinction is used to characterize STS programs. and strategies advocated and used in a professional development program developed in 1983, and called the Iowa Chautauqua Program (ICP). Contrasts between STS and traditional classrooms have been developed from many perspectives following Harms' Project Synthesis final report (Harms & Yager, 1981). For creativity, these contrasts appear in Table 1.

Table 1
Contrasting Student Roles Related to Creativity Skills in Textbooks and STS Sections

Textbook	**STS**
Students decline in their ability to question; the questions they do raise are often ignored because they do not fit into the course outline.	Students ask more questions; such questions are used to develop STS activities and materials.
Students rarely ask unique questions.	Students frequently ask unique questions that excite their own interest, that of other students, and that of the teacher.
Students are ineffective in identifying possible causes and effects in specific situations.	Students are skillful in suggesting possible causes and effects of certain observations and actions.
Students have few original ideas.	Students seem to effervesce with ideas.
Students seldom, if ever, use their science learning beyond the science classroom.	Students use their experience with school science in meeting personal and societal challenges.

The features characterizing STS are all indicative of inquiry as a teaching mode and constructivism as a theory of learning.

Methods and Procedures

This study is designed to contrast two different science teaching modes, namely STS and textbook oriented approaches as differentiated above in terms of measures of student creativity. Student scores attained from use of discrepant events were designed to test various forms of creativity as defined in Assessing Student Understanding in Science (Enger & Yager, 2001). The measures with respect to creativity focus on questions arising from discrepant events related to particular science topics/modules/situations. Such events were administered at least at three points during a defined instructional period. They were used to generate student interest, involvement, and actions involving different projects for individual and small groups of students. Such events acted as pretests (before the module was undertaken), used during a month long module, and as posttests (at the end of a four week module). The protocol also concentrated on the answers/possible explanations of the event and the designs/actions planned to test the validity of the explanations offered for students in classrooms of fifteen key teachers in the ICP program operating in five centers across Iowa. Two parallel classes for each of the fifteen teachers were designated as experimental (STS) and contrast (Textbook) sections. The independent variable was the teaching approach and the dependent variables were learning outcomes used to define creativity. The data reported for this study were collected as pretests and posttests, but also provided typical instructional situations used by all teachers at times between the pre- and post- tests in both their STS and traditional sections. At least one of these midpoint situations was used to establish a uniform way for reporting differences exhibited in creativity between STS and textbook sections.

Teacher and Class Selection

The ICP is an in-service teacher training project developed and coordinated by the Chautauqua staff in the Science Education Center at the University of Iowa. The purpose of the professional development program is to provide ongoing guidance and direction for improving school science from kindergarten to grade twelve (Chautauqua Brochure, 1990). Improvement is accomplished by making science classes more exciting and meaningful for all students through the development of teaching and assessment strategies. which provide a context and a focus on the relationships among science, technology, and society (STS).

To maximize its effectiveness, the project utilizes a model which incorporates the expertise of experienced STS teachers (also called "lead teachers") into the instructional program. All teachers recruited for this inquiry were lead teachers for the project. Therefore, they were all very familiar with STS philosophy as well as the appropriate teaching strategies. As a result of this close collaboration, fifteen experienced STS teachers (of twenty-two invited to be involved) agreed to participate in the study. Five of them taught in grades 4 and 5, five in 6 and 7, and five in 8 and 9. Each teacher selected two classes for the purpose of this study. One served as the treatment (STS) and one as the contrast (textbook) group. Treatment groups were provided experiences (taught) with the STS approach. while contrast groups were taught with traditional textbook oriented methods. Each teacher agreed to follow his/her textbook closely for a full semester–as they had done prior to their experience with STS. They agreed to be as enthusiastic and to strive to meet course objectives for all class sections. They agreed that a difference in teaching approach would be the only instructional variable. They selected units of instruction that would allow careful control for time. The congruence of unit topic permitted identical assessments for each teacher for creativity for all students in the 30 class sessions that were involved in the study. Again the teaching (and research protocol) simply asked students within five minutes to list all the questions they could after being presented with a discrepant event, five minutes to offer explanations, five minutes to suggest ways these explanations could be tested. Data reported here were collected over a four week period on different discrepant events. However, the teachers and students were involved with a larger study. which considered other aspects of learning over an entire semester.

Instructional Strategies

In this study, the two instructional strategies are contrasted, namely, STS and textbook approaches. These two approaches differ in many salient characteristics. The differences include philosophical points of view concerning learning as well as the teaching strategies needed for stimulating learning. Some of the major operational (observable) differences can be seen from the list of contrasts as it appears in Table 2.

Table 2

Contrasts in Terms of Teaching Strategies used in Textbook and STS Sections

Textbook	STS
1. Uses a disciplinary approach; avoids discussion involving other disciplines.	1. Uses interdisciplinary approach if the topics, issue, or problem demands such discussion.
2. Students take passive roles in the planning of their own learning activities.	2. Students take active roles in the planning of their learning activities.
3. Uses topics and problems from the textbooks as vehicles for learning.	3. Uses local issues, problems, and points of curiosity as vehicles for learning.
4. Textbooks shape the course outlines and frameworks for learning activities.	4. Student interest concerning local issues and resources (material and human) shape the course outlines and frameworks for learning activities.
5. Teacher is in role as dispenser of knowledge and textbook is the only source of information.	5. Teacher serves as facilitator/guide to learning; and textbook is absent or serves as but one source of information.
6. Use of labs and activities suggested in textbooks and accompanying lab manuals.	6. Use of local resources (human and materials) to locate information that can be used to achieve the objectives.
7. All learning activities are contained in classrooms and tightly arranged by the class schedule.	7. Learning activities go beyond a given classroom or lab and very often beyond class sessions.
8. Starts with a topic or concept contained in the textbook and ends with examples of applications.	8. Starts with connections, applications, or points of curiosity, and searches for science concepts and/or the resolution of problems.
9. Student tasks involve assimilating information provided by the teacher and textbooks.	9. Student tasks include locating the sources of information as well as gathering and assembling information.

For each pair of treatment-contrast groups, the content topics and time frames were the same. Therefore, the discrepant events developed and selected by each teacher for use for the treatment and contrast classes were the same. The time given for students to indicate their 1) questions, 2) explanations, and 3) tests for the validity of the explanations were the same for all teachers, and for both the STS and textbook sections. Obviously, classroom activities, teaching strategies and student-centeredness varied widely for each teacher when involved with the textbook and with the STS class.

Instruments

The Creativity Domain consists of imagining and creating. This domain promotes the development of students' imagination and creative thinking. It is related to many aspects. such as asking relevant questions, offering possible explanations, and testing ideas. It also includes: visualizing (producing mental images); combining objects and ideas in new ways; producing alternate or unique uses for objects; designing or fantasizing devices and machines; merging; diverging; and converging. Teachers were invited during leadership sessions to recognize creativity in their students as they planned instruction and evoked success in science for all students. Many of these teacher and student descriptions are being analyzed for qualitative differences arising from the same classrooms.

The reliabilities of the research protocols in the creativity domain were established previously with results in the average of 0.88 (using test-retest methods over a five-day period) (Myers, 1988; Mackinnu, 1991; Lu, 1993). In addition, the interrater reliabilities, for consistency in scoring among raters in terms of quality of the student responses, ranged from 0.76 to 0.86.

Scores for various activities following the sharing of at least three discrepant events that were related to the science topic were collected for each module, one prior to teaching the module, one, two, or more times at mid-points (not used as data for this study), and at the end. The numbers represent averages of total numbers of questions generated, explanations offered, and proposed actions/designs proposed for determining the validity of the explanations. Although there were differences in terms of totals in each category, only total scores are used in terms of reporting the results. It may be of interest in future studies to observe and analyze the greater number of questions, and test the accuracy of the explanations (hypotheses) proposed. Perhaps of most importance is the creativity observed and reported in proposing tests for gathering evidence for the validity of the explanations the students offer.

The uniqueness of the questions, explanations, and tests for the accuracy of the explanations were also noted and will be the focus of additional research. Generally the uniqueness of the student responses represented about 15% of the total number; fewer occurred with the suggestions for ways evidence was collected to determine the validity of explanations. There was considerable variation regarding uniqueness among the fifteen teachers. Again, the more unique the responses provided, the more creative a given student was judged to be. Other studies have indicated that STS is particularly successful in terms of enhancing student motivation and mind engagement (Iskander, 1991; Lu, 1993; Liu, 1997; Kimble, 1999). Students are more central in STS classrooms as defined by the policy statement advanced by the National Science Teachers Association (NSTA Handbook, 2004) and as indicated in the list of contrasts previously offered.

Data Collection

As described previously, each teacher was assigned two classes - one served as the treatment and one as the control group. The assignment of students either to treatment or control group was accomplished by use of random procedures established by counselors and administrators in each school district. To insure that both groups had equal ability and starting points to prevent contaminating the experiment, a pretest procedure was applied. The pretests were administered at the beginning of the instruction. and the posttests at the end of each instructional period (usually month long modules).

The duration of the teaching experiment was one full semester, but the data for creativity reported here arises from a single four week teaching module. This time was considered long enough to see the effect of the teaching experiment for all teachers and their respective administrative leaders.

Data Analysis

The data collected in this study were analyzed as follows:

1. To insure that each pair of control and treatment groups was equal in their ability and other background related to the experiment, t-tests were applied to the pretest scores. Since the pretest scores of treatment and the control groups were not significantly different, the effectiveness of the experiment was assessed by using t-test on the posttest scores. Had the pretest scores between each pair of control and treatment group been significantly different , then analyses of covariance with pretest scores as covariates would have been applied.

2. In addition to the t-test analysis performed on each pair of treatment and control groups for each sample as described previously, aggregation of experimental effect across samples was of interest. This was carried out through the calculation of effect size as commonly used in meta-analyses (Hedges at al., 1989). The effect sizes were calculated for posttests scores. In this procedure, the effect size for each class on each measure or test was calculated using the formula:

$$d = \frac{Xt - Xc}{Sc}$$

where:

d	=	the effect size of the given class on a given test
Xt	=	average scores of treatment group
Xc	=	average scores of control group
Sc	=	standard deviation of control group

Then, the standard error of effect size estimate was calculated using the formula:

$$Sd^2 = \frac{nT + nC}{nT \,.\, nC} + \frac{d^2}{2m}$$

where:

Sd	=	standard error of effect size estimate
nT	=	the number of students in the treatment group
nC	=	the number of students in the control group
d	=	the estimated effect size
m	=	the number of degree of freedom (M nT =+ nC -2)

To combine all of the effect sizes from all classes, the weighted average was used. The formula is:

$$davg = \frac{d_1/S_1^2 + d_2/S_2^2 + \ldots + d_n/S_n^2}{1\backslash S_1^2 + 1/S_2^2 + \ldots + 1/S_n^2}$$

where:

davg	=	average effect sizes for the whole group

Sn	=	standard error of effect size estimate for group n
dn	=	effect size estimate for group n

3. To see whether the differences were large enough, the effect sizes were interpreted in terms of normal curve or Gaussian function.

4. To see whether the data collected from individual teachers or the results for all teachers represent a homogeneous or heterogeneous sample, an analysis of heterogeneity was employed. The heterogeneity statistic, Q, is calculated using formula: (Hedges et al., 1989)

$$Q = (((d_1\text{-}d+)/s_1)^2 + ((d_2 - d+)/s_2)^2 + \ldots + (d_n\text{-}d+)/s_n))^2$$

where:

Q	=	the heterogeneity statistic
dn	=	the independent effect size of the sample nth
d+	=	the weighted average of effect size (d+ = davg)
Sn	=	standard error estimate of effect size sample nth

The Q calculated was compared to percentile of the chi-squared distribution with (n-1) degrees of freedom. In addition, the heterogeneity analysis is also presented by means of graphical plots. The benefit with this statistic is in the verification of heterogeneity within both teacher groups. However, it is limited to the sample size of both teacher groups.

Results

The results from statistical analyses for textbook and STS students in the creativity domain are presented in Tables 3, 4, 5, and Figure 1. Tables 3 and 4 present t-values and p-values (t-tests) for pretest and posttest scores. respectively. Table 3 shows the effect sizes for each pair of textbook-STS classes as well as the results of weighted average calculations. Figure 1 describes heterogeneity analyses in a graphical plot. The figure consists of heterogeneity statistics (Qi) for each teacher (i.e., each pair of sample classes), and their respective effect size distributions on a common scale.

Table 1 shows that there are no significant differences on pretest scores for all of the fifteen pairs of classes (i.e., teachers). However, the results with analyses of t-tests on the posttest scores show significant differences for all fifteen teachers, as shown in Table 2. In other words, the teaching approach does have a significant effect on the scores regarding all aspects of the creativity domain that were observed for all fifteen pairs of classes. STS sections produced significantly more creative students than did students in textbook dominated sections.

In addition, the heterogeneity statistics, as shown in Figure 1, is 48.85 85, which exceeds the critical value of 23.68 for α=.05 ($\chi 2$ =14, .95) and 29.14 for α=.01 ($\chi 2$ =14, .99). Statistically, it can be concluded that the magnitude of effect sizes of the teaching approach regarding the creativity domain are heterogeneous or not consistent across classes or teachers. Further examination on Qi statistics and distribution plot (Figure 1) reveals that Teachers 1 (T1) and 3 (T3) have a Qi exceeding the critical value 5.35 for α=.01 (Hedges et al., 1989). Therefore, Teachers 1 and 3 are considered deviant from the rest, at α=.01, and are significantly higher than them.

Table 3

Comparison of Creativity Pretest Scores Prior to Instruction Between STS Sections and Textbook Sections

Teacher	**Nc+Nt**	**Xc**	**Sc**	**Xt**	**St**	**t-Values**	**p-Values**
T1	26+25	23.12	6.43	23.04	8.76	-0.04	> .900
T2	26+27	83.96	33.07	87.67	33.37	0.41	> .500
T3	20+18	76.00	23.71	76.61	25.98	0.08	> .900
T4	23+22	55.65	22.08	54.91	20.94	-0.12	> .900
T5	25+26	65.72	28.44	68.42	26.20	0.35	> .700
T6	22+21	68.50	25.70	76.71	25.58	1.05	> .300
T7	24+26	24.37	9.10	25.31	9.79	0.35	> .700
T8	24+22	61.42	22.91	60.18	23.35	-0.18	> .700
T9	24+23	67.37	21.19	68.04	21.05	0.11	> .900
T10	26+27	65.00	26.65	70.33	25.32	0.75	> .300
T11	16+17	71.69	24.31	76.00	24.38	0.51	> .500
T12	28+29	24.39	8.17	24.00	8.99	-0.17	> .700
T13	27+25	69.63	26.17	72.36	24.11	0.39	> .500
T14	26+25	61.58	22.26	66.12	21.03	0.75	> .300
T15	25+27	63.24	23.15	64.93	22.58	0.27	> .700

Note: Nc+Nt = number of students in STS and textbook sections, Xc= average scores for students in STS sections, Sc = standard deviations for STS sections, Xt = average scores for students in textbook sections, St = standard deviations for textbook sections

Table 4

Comparison of Creativity Posttest Scores Following Instruction Between STS Sections and Textbook Sections

Teacher	Nc+Nt	Xc	Sc	Xt	St	t-Value	p-Value
T1	26+25	23.96	5.77	52.72	16.96	8.17	< .000**
T2	26+27	79.42	33.93	163.96	50.98	7.08	< .000**
T3	20+18	74.90	20.06	163.33	39.68	8.80	< .000**
T4	23+22	63.43	22.40	115.59	36.66	5.79	< .000**
T5	25+26	72.00	32.96	135.77	47.67	5.54	< .000**
T6	22+21	79.59	29.28	133.95	34.07	6.03	< .000**
T7	24+26	25.04	10.08	46.92	15.59	5.84	< .000**
T8	24+22	65.92	25.76	106.77	27.76	5.18	< .000**
T9	24+23	68.21	22.65	115.09	31.35	5.89	< .000**
T10	26+27	69.58	33.28	127.96	38.78	5.87	< .000**
T11	16+17	72.75	23.98	125.71	36.15	4.93	< .000**
T12	28+29	24.43	8.82	41.48	12.84	5.82	< .000**
T13	27+25	74.59	29.18	125.76	37.23	5.54	< .000**
T14	26+25	69.23	27,61	113,04	27.55	5.67	< .000**
T15	25+27	62.96	23.28	117.15	31.88	6.95	< .000**

Note: Nc+Nt = number of students in STS and textbook sections, Xc = average scores for students in STS sections, Sc = standard deviations for STS sections, Xt = average scores for students in textbook sections, St = standard deviations for textbook sections

Table 5
Average Scores, Standard Deviations, and Effect Sizes for Posttest Scores Concerning Creativity

Teacher	XT	XC	Sc	D (ES)	Sd
T1	52.720	23.962	5.765	4.988	0.576
T2	163.963	79.423	33.933	2.491	0.369
T3	163.33	74.900	20.063	4.408	0.613
T4	115.591	63.434	22.401	2.328	0.399
T5	135.769	72.000	32.960	1.993	0.342
T6	133.952	75.591	29.286	1.993	0.376
T7	46.923	25.042	10.084	2.169	0.359
T8	106.773	65.917	25.760	1.586	0.340
T9	115.087	68.208	22.649	2.070	0.364
T10	127.963	69.577	33.284	1.754	0.325
T11	125.706	72.750	23.982	2.208	0.447
T12	41.483	24.428	8.821	1.933	0.323
T13	125.760	74.593	29.185	1.753	0.328
T14	113.040	69.231	27.613	1.586	0.323
T15	117.148	62.960	23.280	2.327	0.362
All Combined (weighted averages)				2.120	0.095

Note: X_T = Average score on posttest for textbook sections, X_C= Average score on posttest for STS sections

Figure 1:
Heterogeneity Plot of STS-Textbook Effect Sizes for Posttest Scores on Creativity
(Significant at α=.05., ** Significant at α=.01.)*

Teacher	Qi	Minimum	Average	Maximum
		1.58	2.12	4.99
-		———+———	———x———	———+———
T1	24.76			L—x—U
T2	1.01		L—x—U	
T3	13.95			L—x—U
T4	0.29		L—x—U	
T5	0.29		L—x—U	
T6	0.11		L—x—U	
T7	0.02		L—x—U	
T8	2.46		L—x—U	
T9	0.02		L—x—U	
T10	1.26		L—x—U	
T11	0.04		L—x—U	
T12	0.33		L—x—U	
T13	1.25		L—x—U	
T14	2.73		L—x—U	
T15	0.33		L—x—U	
Sum	48.85 * *			

Discussion

All t-test analyses on pretest scores for all of the fifteen pairs of the control-treatments show that none of them are significant at either α=.05 or α=.01. This means that all of the fifteen pairs of the classes have equal starting points regarding the creativity skills tested at the beginning of the experiment. However, the t-tests conducted on posttest scores at the end of experiment indicate that all of them are significantly different either at α=.05 or α=.01. This suggests that the STS approach does offer an advantage over the traditional textbook oriented approaches in encouraging growth in the creativity domain, particularly in terms of quantity number of questions generated by a discrepant event, the explanations offered, and the suggested tests for determining the validity of the explanations. On the other hand, the results are heterogeneous and not consistent across the fifteen pairs of classes or teachers. This heterogeneity suggests that the results can have different magnitudes for different implementations. Factors, such as topic selection, local resources (human and materials), and teachers probably contribute much in terms of the attainment of creativity skills. In many ways, the more general focus on the broader goals of science education in the STS sections seems to suggest the cause for the development of more creativity in STS sections. The teachers in the STS sections encouraged more student questions, encouraged more student hypothesizing, and stimulated more students to seek evidence for the validity of the explanations they offered. No such forum was provided in the control sections where all the ideas, activities, and evaluations focused on what was included in the textbook.

Conclusions

Classes taught with the STS approach resulted in students who scored significantly higher than what was attained with the comparable textbook oriented approaches with respect to growth in terms of creativity when it is defined as number of questions raised, explanations offered, and suggestions for determining the accuracy of the explanations offered. The magnitude of the experimental effects was found to be heterogeneous and not consistent for the fifteen teachers.

Only few unique questions and explanations were found from students from textbook sections. Virtually no suggestions for testing the validity of the explanations were found for students in the textbook sections. Further research is contemplated regarding differences in terms of quality and quantity of student suggestions for tests to determine the validity of suggested tests among the fifteen teachers.

Other research is underway to test the success of new teachers who first move to STS as a means of achieving the reform visions included in the National Science Education Standards (1996). In addition, it would be useful to know if similar results occur across the curriculum.

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