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AUTHOR Bitner, Betty L.

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ABSTRACT

The purpose of this causal-comparative study was to compare reasoning level, American College Test (ACT) science, process skills, and physical science misconceptions of preservice elementary and secondary science teachers and to investigate gender differences. The stratified randomly drawn sample (n=68) consisted of preservice elementary and secondary science methods teachers. During the first two weeks of classes, the Group Assessment of Logical Thinking (GALT), the Integrated Process Skills Test II (TIPS II), and the Physical Science Test (PST) were administered. Seventy-six percent of the sample (85% of secondary and 68% of elementary) were formal reasoners. Fifty percent or more of the preservice elementary teachers correctly answered all items on TIPS II except one. Sixty-five percent or more of the preservice secondary teachers had correct responses to the TIPS items. Misconceptions in electromagnetic phenomena/electricity/light, motion, and mass were found most often. Significant two-way ANOVAs (p .01) were found on the ACT Science in favor of the secondary teachers and on the PST in favor of males and secondary teachers. (Author)

PRESERVICE ELEMENTARY AND SECONDARY SCIENCE METHODS TEACHERS: COMPARISON OF FORMAL REASONING, ACT SCIENCE, PROCESS SKILLS, AND PHYSICAL SCIENCE MISCONCEPTIONS SCORES

Betty L. Bitner

Associate Professor of

Curriculum and Instruction

Southwest Missouri State University

Springfield, Missouri 65804

(417) 836-5137 or 5795

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Abstract

The purpose of this causal-comparative study was to compare reasoning level, ACT science, process skills, and physical science misconceptions of preservice elementary and secondary science teachers and to investigate gender differences. The stratified randomly drawn sample ($N = 68$) consisted of preservice elementary and secondary science methods teachers. During the first two weeks of classes, the GALT, TIPS II, and PST were administered. Seventy-six percent of the sample (85% of secondary and 68% of elementary) were formal reasoners. Fifty percent or more of the preservice elementary teachers correctly answered all items on TIPS II except one. Sixty-five percent or more of the preservice secondary teachers had correct responses to the TIPS items. Misconceptions in electromagnetic phenomena/electricity/light, motion, and mass were found most often. Significant two-way ANOVAs ($p < .01$) were found on the ACT Science in favor of the secondary teachers and on the PST in favor of males and secondary teachers.

Purposes of the Study

In this causal-comparative study, reasoning level, ACT science, process skills, and physical science misconceptions scores of preservice elementary and secondary science methods courses were compared. Also investigated were gender differences.

Significance of the Study

The goal of science education is the production of scientifically and technologically literate citizens (Yager, 1984). The responsibility of such rests on the schools and universities (Hazen & Trefil, 1991). Acquisition and utilization of thinking skills and processes, e.g., the 10 rational powers (Education Policies Commission, 1961), five formal operational modes (Capie, Newton, Tobin, 1981; DeCarcer, Gabel, & Staver, 1978; Inhelder & Piaget, 1958; Lawson, 1982; Lawson, 1985; Linn, 1982), process skills (Burns, Okey, & Wise, 1985; Padilla, 1987), critical thinking skills (Adler, 1983; Blosser, 1985; Boyer, 1983; National Science Board Commission, 1983) are essential for functioning in the "Information Age Society" (Costa, 1989; Naisbitt, 1982; Peters & Waterman, 1982; Resnick & Klopfer, 1989; Tofler, 1980). Formal operational reasoning predicts achievement in science and mathematics (Bitner, 1986, 1988a, 1988b, 1991b; Hofstein & Mandler, 1985; Howe & Durr, 1982; Lawson, 1983; Lawson, Lawson, & Lawson, 1984) and critical thinking abilities (Bitner, 1988a, 1988b, 1991b).

Baker (1991); Bitner (1991a); Champagne (1983); Champagne, Klopfer, and Anderson (1980); Clement (1982); and Lawrenz (1986) have reported instances of science misconceptions among high school and university students and teachers. The most frequently identified physical science misconceptions related to electromagnetic phenomena/electricity/light, motion, and mass. Lawrenz (1986) called for the resolution of science misconceptions; Clement & Brown (1984) recommended the use of analogical reasoning in overcoming science misconceptions. Lawson, Abraham, & Renner (1989) recommended the constructivist process.

Design

In this causal-comparative study, frequency and two-way ANOVA (SPSS, 1990) were used to analyze the data. The independent variables were gender and methods class (elementary or secondary); the dependent variables were formal reasoning, ACT Science, process skills, and physical science misconceptions scores.

Sample

The stratified randomly drawn sample ($N = 68$) for this causal-comparative study consisted of preservice elementary and secondary science methods teachers in a midwestern university with a student enrollment of approximately 20,000. The Teacher Education Program has an enrollment of approximately 2,500. For admittance into the Teacher Education Program, students must have completed 45 credit hours with a GPA of 2.4, an American College Test (ACT) composite of 20, and a College Basic Academic

Subjects (C-BASE) composite of 235. The preservice elementary teachers are required to complete three science courses plus the elementary science methods course. The preservice secondary science teachers must meet the requirements of their major.

The sample consisted of eighteen males and forty females. On the average, the preservice elementary teachers were 23.52 years of age (SD = 4.63, with a range of 20 - 40) and had a college GPA of 3.31 on a scale of 4.0 (SD = .48). The preservice secondary science teachers averaged 29.54 in age (SD = 9.14), with a range of 20 - 53. The mean GPA for this group was 3.15 (SD = .47). Of the elementary teachers, 12% had completed no earth science courses and 18% had completed no physical science courses. The elementary majors had a mean ACT composite score of 23.56 (SD = 3.13 with a range of 20 - 32) and a mean ACT Science sub-test of 24.53 (SD = 4.16 and range of 16 - 34). The secondary subjects' average ACT composite score was 25.15 (SD = 3.38 with a range of 20 - 31) with a M = 27.35, SD = 3.22, and range of 20 - 32 on the Science sub-test. The average C-BASE composite for the elementary group was 326.16 (SD = 44.88 with a range of 241 - 414); the mean C-BASE Science was 330.59 (SD = 56.08, and range of 225 - 416). Somewhat higher results were found for the secondary teachers on the C-Base composite (M = 357.75, SD = 46.17, range of 256-444) and Science sub-test (M = 372.45, SD = 61.29, range 236 - 466).

Instrumentation

Prior to admittance into the Teacher Education Program, the preservice teachers had taken the ACT and C-BASE. During the first two weeks of classes (1991 spring, summer, and fall), the Group Assessment of Logical Thinking (GALT) (Roadrangka, Yeany, & Padilla, 1982), the Integrated Process Skills Test II (TIPS II) (Okey, Wise, & Burns, 1982), and the Physical Science Test (Lawrenz, 1986) were administered to the population from which the sample was randomly selected. Included in the subsequent paragraphs are descriptions of the content, validity, and reliability of the instruments.

Because the ACT is a widely used and accepted test for college entrance, the validity and reliability of the instrument will not be discussed. Suffice it to say that the mean is 20 and the standard deviation 6.

C-BASE, a criterion-referenced test, measures knowledge and skills in four academic areas, i.e., English, mathematics, science, and social studies (Osterlind & Mertz, 1990). It is intended to assess the knowledge and competencies in the four academic areas covered in the general education component of an undergraduate degree program. The test consists of two categories: the four content domains and three reasoning competencies. The reasoning competencies, arranged hierarchically, include interpretive reasoning, strategic reasoning, and adaptive reasoning. Presently, C-BASE is used to admit candidates into teacher education programs in the State. For admittance a cut-off score of 235 is required. The numeric scores range from 40 to 565 points ($M = 300$, $SD = 65$). The internal consistency (K-R 20) of C-BASE ranged from .77 in English to .89 in mathematics. Validity was established (see Osterlind & Mertz, 1990). Criterion-related evidence was established with the ACT, SAT, and GPA. A strong relationship was found among the C-BASE contents domains and the ACT, SAT-V, SAT-Q, and GPA categories. Of specific interest in this study are the reasoning competencies and the science domain test which consist of 41 items, measuring laboratory and field work and fundamental concepts in life and physical sciences.

The abbreviated GALT, a twelve-item paper and pencil test of logical thinking consists of six modes of reasoning, one concrete operational (i.e., conservation) and five formal operational (i.e., proportional reasoning, controlling variables, probabilistic reasoning, correlational reasoning, and combinatorial logic). The test format for all items except the two combinatorial logic problems consists of an illustration of the problem and multiple choice response for both the correct answer and justification. For the combinatorial logic items, students must provide logical combinatorial patterns. The GALT was chosen to measure formal reasoning because of the validity and reliability results obtained by Roadrangka et al. (1983) on a sample of students ranging from sixth grade through college. Construct validity was established by determining convergent validity with Piagetian Interview Tasks (.80) and by using the principal components method of factor analysis. The scores on the TIPS II were used to establish the criterion-related validity of the GALT. The correlation between the total GALT score and the total TIPS II was .71. A .85 coefficient was found for internal consistency by calculating Cronbach's alpha (see Roadrangka et al., 1983).

TIPS II, a thirty-six item multiple-choice test, measures five process skill objectives (i.e., identifying variables, identifying and stating hypothesis, operationally defining, designing investigations, and graphing and interpreting data). The test was designed to measure process skills of students in grades 7 - 12. Burns et al. (1985) reported mean scores ranging from 15.91 for seventh graders to 25.27 for students in grades 10 -12. Cronbach's alpha reliability coefficient for the total test was .86. The item difficulty indices ranged from .15 to .87 (M = .53). A range of .11 to .64 (M = .35) was reported for the point biserial discrimination indices.

PST, a thirty-one item multiple-choice test, measures physical science concepts. Lawrenz (1986) constructed PST from the National Assessment of Educational Progress's (NAEP, 1978) released items for physical science for 17 year olds. The Kuder-Richardson reliability coefficient for the thirty-one items was .80. Lawrenz (1986) administered the PST to a sample of inservice elementary teachers who had voluntarily enrolled in a science course. She reported an item difficulty ranging from 34% to 90% and a mean score of 19 with a range from 5 - 30. Over 50% of the inservice teachers correctly answered items focusing on atomic energy, off-center balancing, averaging, lenses, batteries, density, stars, heat exchange, and chemical reactions. A score of 21 or below was reported for two-thirds of the sample. Fifty percent or less responded correctly to items 7, 20, 21, 23, 24, 25, 26, 27, 28, 29, and 31. Of these eleven items, Lawrenz identified items 20, 21, 23, 25, 28, and 29 as rather "content specific or fact oriented" (p. 656). Difficulty with items 24, 27, and 31 indicate misconceptions about mass. The percent correctly answering items 24, 27, and 31 was 40, 50, and 36, respectively. Only 63% of the teachers correctly answered item 26, indicating a misconception about motion. She concluded that difficulty with items 7, 23, 25, and 28 indicated a misconception about electromagnetic phenomena/ electricity/light. The percent of the teachers responding correctly to items 7, 23, 25, and 28 was 34, 43, 41, and 38, respectively.

Results

Means, Standard Deviations, and Item Difficulty on the GALT

In Table 1 are reported the means, standard deviations, and item difficulty for the six reasoning modes in the GALT. Of the six reasoning modes in the GALT, correlational reasoning was the most difficult for the total sample and both groups.

Insert Table 1 about here

The distribution of the sample (N = 68) according to reasoning levels was 76% formal and 24% transitional (see Table 2). Sixty-eight percent of the preservice elementary teachers were formal; 32% were transitional. Somewhat higher percentages (i.e., 85% formal and 15% transitional) were found for the secondary teachers.

Insert Table 2 about here

Frequencies and Percents on the TIPS II

The frequencies and percents for the 36 items on the TIPS II are included in TABLE 3. For this sample, the lowest responding rate was 54% for item 27, an identifying and stating hypothesis objective. Only 39% of preservice elementary teachers correctly answered item 27. The percentage correctly answering the thirty-six items for the secondary group was 65% or greater. For the elementary group, the percentage of correct responses was below 65% for four items (2, 13, 15, 27). Items 13 and 15 require the identification of variables. Item 2 is an operationally defining objective. The means and standard deviations on the TIPS II were 29.41 and 6.31 (elementary) and 31.85 and 3.58 (secondary), respectively.

Insert Table 3 about here

Frequencies and Percents on the Physical Science Test

Fifty percent or less of the sample (N = 68) responded correctly to items 7 (magnetic field), 21 (temperature scales), 22 (speed), 24 (gas mass), 25 (electromagnetic field), 26 (motion), 28 (light), and 31 (mass) (see Table 4). The mean score for the sample was 21 (SD = 4.93). Only four percentages (13, evolution star; 25, electromagnetic field; 27, mass earth; and 29, chemical reaction) fell below 50% for the secondary group. The mean and standard deviation for the secondary group were 23.91 and 3.91, respectively. Fifty percent or less of the elementary group correctly responded to items 7 (magnetic field), 17 (mass), 19 (particles), 20 (mixtures), 21 (temperature scales), 22 (speed), 23 (electrical charge), 24 (gas mass), 25 (electromagnetic), 26 (motion), 27 (mass earth), 28 (light), 29 (chemical reaction), 30 (atoms), and 31 (mass). The mean and standard deviation for the elementary group were 19.09 and 4.16, respectively. Items measuring electromagnetic phenomena/electricity/light, motion, and mass were the most difficult.

Insert Table 4 about here

Results of the Two-Way ANOVAs

The results of the two-way ANOVAs (GALT by gender and methods teacher, elementary or secondary) and (TIPS II by gender and methods teacher, elementary or secondary) were not significant at the .01 level. However, the two-way ANOVAs for ACT Science and PST were significant. The preservice secondary science methods teachers (M = 27.35, SD = 3.22) performed significantly higher on the ACT Science sub-test than the preservice elementary science methods teachers (M = 24.53, SD = 4.27), F(1,66) = 7.16, p < .01. Gender differences were not found on the ACT Science. Both gender and methods teacher had a significant effect on the PST. The preservice secondary science methods teachers (M =23.91, SD = 3.81) outperformed the preservice elementary science methods teachers (M = 18.09, SD = 4.16) on the PST, F(1,66) = 21.77, p < .001). The males (M = 24.83, SD = 3.52) performed better than the females (M = 19.62, SD = 4.74) on the PST, (F (1,66) = 7.07, p < .01).

Conclusions

Seventy-six percent of the sample (N = 68) was functioning at the formal operational level. A higher percentage (85%) of the preservice secondary science methods teachers were formal reasoners than the preservice elementary teachers (68%). The percentage of formal reasoners in the elementary group was higher than the 59% reported by Bitner (1991). Correlational reasoning was the most difficult for this sample, a result previously found by Bitner (1991a, 1991b).

The lowest responding rate was 54% for item 27, an identifying and stating hypothesis. The preservice elementary teachers experienced more difficulty with this item than the secondary teachers. The elementary teachers also had some difficulty with two identification of variables items (13 and 15) and one operationally defining item (2). The percentage correctly answering the thirty-six process items for the secondary group was 65% or higher. It was expected that the secondary teachers would perform better than the elementary teachers because of their many laboratory experiences.

The results of PST for the present study are similar to those reported by Baker (1991), Bitner (1991) and Lawrenz (1986). The findings indicate misconceptions about electromagnetic phenomena/electricity/light, motion, and mass. As expected, the secondary teachers had less physical science misconceptions than the elementary teachers.

It was expected that the preservice secondary science teachers would perform better than the preservice elementary science methods teachers because of the difference in science background. Gender difference, however, was not anticipated.

The difference in ACT Science sub-test in favor of the secondary group may be a factor in students' decision to major in science. The difference may emanate from the difference in high school science preparation.

Overall, this sample performed well on the GALT and TIPS II. However, results on the PST indicate physical science misconceptions, especially for the preservice elementary teachers. If the responsibility of producing scientifically literate citizens rests on the schools and universities (Hazen & Trefil, 1991), it is imperative that we evaluate what science is being taught and how it is being taught. The researcher recommends the constructivist approach to teaching science.

References

Adler, M. L. (1983). Paideia problems and possibilities. A consideration of questions raised by the paideia proposal. New York: Collier Books Macmillan.

Baker, R. B. (1991). Comparison of physical science misconceptions in three levels of introductory university physics classes. Unpublished master thesis, Southwest Missouri State University, Springfield.

Bitner, B. L. (1986, March). The GALT: A measure of logical thinking ability of eighth grade students and a predictor of science and mathematics achievement. Paper presented at the annual meeting of the National Association for Research in Science Teaching, San Francisco, CA.

Bitner, B.L. (1991a, April). College science course, ACT science, C-Base science, and GALT: Predictors of science process skills and physical science misconceptions. Paper presented at eh annual meeting of the National Association for Research in Science Teaching, Lake Geneva, WI.

Bitner, B. L. (1991b). Formal operational reasoning modes: Predictors of critical thinking abilities and grades assigned by teachers in science and mathematics for students in grades nine through twelve. Journal of Research in Science Teaching, 28 (3), 265-274.

Bitner, B. L. (1988a). Logical and critical thinking abilities of sixth through twelfth grade students and formal reasoning modes as predictors of critical thinking abilities and academic achievement. (ERIC Document Reproduction Service No. ED 293 715)

Bitner, B. L. (1988b). Logical and critical thinking abilities of sixth through twelfth grade students and formal reasoning modes as predictors of critical thinking abilities and academic achievement. Paper presented at the annual meeting of the National Association for Research in Science Teaching, Lake Ozark, MO.

Blosser, P. E. (1985, Fall). Science education for the year 2000 and beyond. In R. K. James & V. R. Kurtz, Science and mathematics education for the year 2000 and beyond. (pp.52-82). Bowling Green, OH: School Science and Mathematics Association.

Boyer, E. L. (1983). High school: A report on secondary education in America. New York: Harper & Row.

Burns, J.C., Okey, J.R., Wise, K.C. (1985). Development of an integrated process skill test: TIPS II. Journal of Research in Science Teaching, 22, 169-177.

Capie, W., Newton, R., & Tobin, K. G. (1981, May). Developmental patterns among formal reasoning skills. Paper presented at the Eleventh Annual symposium of the Jean Piaget Society, Philadelphia, PA.

Champagne, A. (1983), Structuring process skills and the solution of verbal problems involving science concepts. Science Education, 65, 493-512.

Champagne, A., Klopfer, E., & Anderson, D. (1980). Effecting changes in cognitive structures amongst physics students. (ERIC document Reproduction Service No. ED 229 238)

Clement, J. (1982). Students' alternative conceptions in mechanics: A coherent system of preconceptions? (In Proceedings of the International Seminar, Misconceptions of Science and Mathematics).

Clement, J., & Brown, D. (1984). Using analogical reasoning to deal with "deep misconceptions in physics. (ERIC Document Reproduction Service No. ED 286 745)

DeCarcer, I. A., Gabel, D. L., & Staver, J. R. (1978). Implications of Piagetian research for high school science teaching: A review of the literature. Science Education, 62, 571-583.

Costa, A. (1989). In L. B. Resnick & L. E. Klopfer, Toward the thinking curriculum: Current cognitive research. 1989 ASCD yearbook. Alexandria, VA.: Association for Supervision and Curriculum Development.

Hazen, R., & Trefil, J. (1991). General science courses are the key to scientific literacy. The Chronicle of Higher Education, 44-45

Hofstein, A., & Mandler, V. (1985). The use of Lawson's test of formal reasoning in the Israeli science education context. Journal of Research in Science

Teaching, 22, 141-152.

Howe, A. C., & Durr, B. P. (1982). Analysis of an instructional unit for level of cognitive demand. Journal of Research in Science Teaching, 19, 217-224.

Inhelder, B., & Piaget, J. (1958). The growth of logical thinking from childhood to adolescence. U.S.A.: Basic Books.

Lawrenz, F. (1986). Misconception of physical science concepts among elementary school teachers. School Science and Mathematics, 86, 655-660.

Lawrenz, F. (1986). Physical Science Test.

Lawson, A. E. (1982). Formal reasoning, achievement, and intelligence: An issue of importance. Science Education, 66, 77-83.

Lawson, A. E. (1983). Predicting science achievement: The role of developmental level, disembedding ability, mental capacity, prior knowledge, and beliefs. Journal of Research in Science Teaching, 20, 117-129.

Lawson, A. E. (1985). A review of research on formal reasoning and science teaching. Journal of Research in Science Teaching, 22, 569-617.

Lawson, A. E., Abraham, M. R., & Renner, J. W. (1989). A theory of instruction: Using the learning cycle to teach science concepts and thinking skills (NARST Monograph, No. 1). National Association for Research in Science Teaching.

Lawson, A. E., Lawson, D. I., & Lawson, C. A. (1984). Proportional reasoning and the linguistic abilities required for hypothetico-deductive reasoning. Journal of Science Teaching, 12, 347-358.

Linn, M. C. (1982). Theoretical and practical significance of formal reasoning. Journal of Research in Science Teaching, 19, 727-742.

National Science Board Commission on Precollege Education in Mathematics, Science and Technology. (1983). Educating Americans for the 21st century: A plan of action for improving mathematics, science and all technology education for all American elementary and secondary students so that their achievement is the best in the world by 1995. DC: National Science Foundation.

Okey, J.R., Wise, K.C., & Burns, J.C. (1982). Integrated process skills test II. University of Georgia: Department of Science Education.

Osterlind, S.J., & Mertz, W.R. (1990). College BASE technical manual. University of Missouri: Center for Educational Assessment.

Padilla, M. (1987). Using NSTA teacher standards for preparing and evaluating NCATE folios.

Resnick, L. B., & Klopfer, L. E. (1989). Toward the thinking curriculum: Current cognitive research. 1989 ASCD yearbook. Alexandria, VA: Association for Supervision and Curriculum Development.

Roadrankga, V., Yeany, R., & Padilla, M. (1982, December). GALT. Group test of logical thinking. University of Georgia, Athens, GA.

Roadrangka, V., Yeany, R. H., & Padilla, M. J. (1983,April). The construction and validation of group assessment of logical thinking (GALT). Paper presented at the annual meeting of the National Association for Research in Science Teaching, Dallas, TX.

SPSS Reference Guide (3rd ed.). (1990). Chicago, IL: SPSS Inc.

Yager, R.E. (1984). The major crisis in science education. School Science and Mathematics, 84, 189-198.

Table 1

A Comparison of Means, Standard Deviations, and Item Difficulty on the GALT (N = 68)

Reasoning Ability	Elementary (n = 34)			Secondary (n = 34)			Total (N = 68)		
	M	SD	%	M	SD	%	M	SD	%
Conservation	1.74	.57	79	1.85	.36	85	1.79	.48	82
Item 1	.94	.24	94	.82	.39	82	.97	.17	97
Item 4	.79	.41	79	.82	.39	82	.81	.40	81
Proportionality	1.53	.56	56	1.77	.43	76	1.65	.51	66
Item 8	.85	.36	85	.88	.33	88	.87	.34	87
Item 9	.68	.48	68	.82	.39	82	.75	.44	75
Controlling Variables	1.53	.66	29	1.47	.43	53	1.50	.64	57
Item 11	.79	.41	79	.82	.39	82	.81	.40	81
Item 13	.74	.45	74	.65	.49	65	.69	.47	69
Probability	1.68	.68	79	1.77	.55	82	1.72	.62	81
Item 15	.79	.41	79	.85	.36	85	.82	.38	82
Item 16	.88	.33	88	.88	.33	88	.88	.33	88
Correlational	.65	.81	21	.85	.70	18	.75	.76	19
Item 17	.38	.49	38	.68	.48	68	.53	.50	53
Item 18	.24	.43	24	.24	.43	24	.24	.43	24
Combinatorial	1.74	.45	74	1.62	.55	65	1.68	.50	69
Item 19	.94	.24	94	.94	.24	94	.94	.24	94
Item 20	.82	.39	82	.77	.43	76	.79	.41	79
GALT Total	8.85	2.06		9.38	1.67		9.12	1.88	

Table 2

Levels of Rea:oning on the GALT (N = 68)

Group	Reasoning Level					
	Formal[a]		Transitional[b]		Concrete[c]	
	N	%	N	%	N	%
Elementary						
(n =34)	23	68	11	32	0	0
Female						
(n = 31)	21	63	10	32	0	0
Male						
(n = 3)	2	67	1	33	9	0
Secondary						
(n = 34)	29	85	5	15	0	0
Female						
(n = 19)	16	84	3	16	0	0
Male						
(n = 15)	13	87	2	13	0	0
Total						
(N = 68)	52	76	16	24	0	0

[a]Score = 8-12 (M = 9.98, SD = 1.13)

[b]Score = 5-7 (M = 6.31, SD = .70)

[c]Score = 0-4

TABLE 3

Frequency and Percent on TIPS II for Sample (N=68)

	Elementary (n = 34)		Secondary (n = 34)		Total (n =68	
Objectives/Items	F	%	F	%	F	%
Identifying Variables						
1	30	88	25	74	55	81
3	32	94	32	94	64	94
13	21	62	26	76	47	69
14	28	82	30	88	58	85
15	18	53	29	85	47	69
18	23	68	22	65	45	66
19	27	79	30	88	57	84
20	25	74	30	88	55	81
30	27	76	22	65	48	71
31	30	88	30	94	62	91
32	27	79	31	91	58	85
36	24	71	27	82	51	76
Identifying and Stating Hypothesis						
4	30	88	32	94	62	91
6	26	76	31	91	57	84
8	30	88	30	88	60	88
12	30	88	34	100	64	94
16	26	76	32	94	58	85
17	33	97	34	100	67	99
27	13	39	23	68	36	54
29	34	100	34	100	68	100
35	29	85	32	94	61	90
Operationally Defining						
2	20	59	25	74	45	66
7	30	88	30	88	60	88
22	32	94	34	100	66	97
23	24	71	31	91	55	81
26	33	97	31	91	64	94
33	30	88	30	88	60	88
Designing Investigations						
10	31	91	34	100	65	96
21	33	97	28	82	61	90
24	31	91	34	100	65	96
Graphing and Interpreting Data						
5	25	74	26	76	51	75
9	32	94	32	94	64	94
11	34	100	33	97	67	99
25	29	85	30	88	59	87
28	31	91	33	97	64	94
34	32	65	28	82	50	74
Mean	29.41		31.85		30.63	
Standard Deviation	6.31		3.58		5.24	

Table 4

Frequency and Percent on the Physical Science Test (N = 68)

Item	Elementary (n = 34)		Secondary (n = 34)		Total (n = 34)	
	F	%	F	%	F	%
1-Atoms	33	97	32	94	65	96
2-Balances	27	79	23	68	50	74
3-Weights	30	88	31	91	60	90
4-Temperature	33	97	33	97	66	97
5-Hypothesis	30	88	33	97	63	93
6-Reflection	26	76	31	91	57	84
7-Magnetic Field	8	24	20	59	28	41
8-Voltage	23	68	24	71	47	69
9-Lens	27	79	30	88	57	84
10-Combustion	26	76	32	94	58	85
11-Path	19	56	60	59	39	57
12-Density	23	68	30	88	53	78
13-Evolution Star	26	76	4	27	53	78
14-Star	30	88	31	91	61	90
15-Heat	21	62	22	68	44	65
16-Chemical Bonds	28	82	32	94	60	88
17-Mass	14	41	25	74	39	57
18-Crystals	26	76	31	91	57	84
19-Particles	16	47	30	88	46	66
20-Mixture	16	47	22	65	38	56
21-Temperature Scales	10	29	20	59	30	44
22-Speed	10	29	21	62	31	46
23-Electrical Charge	3	9	30	88	56	82
24-Gas Mass	9	26	20	59	29	43
25-Electromagnetic	3	7	3	23	30	44
26-Motion	10	29	23	68	33	49
27-Mass Earth	14	41	2	28	42	62
28-Light	9	26	18	53	27	40
29-Chemical Reaction	16	47	3	9	19	56
30-Atoms	15	44	29	85	44	65
31-Mass	4	12	18	53	22	33
Mean	18.09		23.91		21.00	
Standard Deviation	4.16		3.91		4.93	