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ABSTRACT

In this predictive study, the variables of College Basic Academic Subjects Examination (C-BASE) Science score, American College Test (ACT) Science score, Group Assessment of Logical Thinking (GALT) score, and total number of college science courses completed were investigated as predictors of science process skills and physical science misconceptions. Also investigated were the level of formal operational reasoning, science process skills, and physical science misconceptions of preservice elementary teachers. The sample consisted of 4 males and 25 females enrolled in an elementary science methods course. Prior to admittance into the Teacher Education Program, the preservice elementary teachers had taken the ACT and the C-BASE. During the first 2 weeks of the classes, the GALT, the Integrated Process Skills Test II (TIPS II), and the Physical Science Test (PST) were administered to the sample. The results of these tests and the number of college science courses completed were then analyzed. The purposes of the study, significance of the study, method, instrumentation, statistical analysis of data procedures, results, conclusions, and 46 references are included. (Author/KR)

College Science Courses, ACT Science, C-Base Science, and GALT: Predictors of Science Process Skills and Physical Science Misconceptions

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Abstract

In this predictive study, the C-BASE Science score, ACT Science score, GALT score, and total number of college science courses completed were investigated as predictors of science process skills and physical science misconceptions. Also investigated were the level of formal operational reasoning, science process skills, and physical science misconceptions of preservice elementary teachers. The literature review uncovered no predictive research studies in which the above variables were used as independent and dependent variables. The sample (N = 29) consisted of four males and 25 females enrolled in an elementary science methods course in a midwestern university with a student enrollment of approximately 20,000. On the average, the subjects were 23.1 years of age (SD = 3.15, with a range of 21 - 34) and had a college GPA of 3.27 on a scale of 4.0 (SD = .43, with a range of 3.0 - 4.0). The number of college science courses completed ranged from 1 to 8 with a mean of 3.9. Of the sample, 20 (71%) had completed only one physical science course, 21 (75%) had taken only one earth science course, and 20 (71%) had completed one biological science course. Twenty-nine percent of the sample had completed two to four biological science courses. The subjects' average ACT composite score was 23.03 (SD = 2.61 with a range of 20 - 30) with a M = 23.82, SD = 4.12, and range of 16 - 32 on the Science sub-test. Their average C-BASE composite was 321 (SD = 45.46 with a range of 241 - 414) with a M = 323.52, SD = 62.70, and

range of 215 - 413 on the science sub-test. 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 to the sample. The validation studies on the three instruments indicate that the instruments are valid and reliable. Fifty-nine percent of the sample is functioning at the formal operational level. Correlational reasoning was the most difficult for this sample. Overall, the preservice elementary teachers performed well on the TIPS II. The males performed better that the females. Item 27 seemed to present the most difficulty for this sample. The results on the PST seemed to indicate misconceptions of physical science concepts. This sample had some of the same problems as a sample of inservice elementary teachers. The majority of problems related to misconceptions of mass, motion, and electromagnetic phenomena/electricity/ light. The number of college science courses completed, science sub-tests on the ACT and C-BASE, and the GALT score were all significant predictors of science process skills and physical science misconceptions. It was anticipated that the GALT would contribute the most variance in process skills because the criterion-related reliability between the GALT and TIPS II was found to be .71. The C-BASE contributed the most variance in understanding physical science concepts. Perhaps this is attributable to the C-BASE's emphasis upon reasoning competencies. Finding the number of college science courses, science sub-tests on the ACT and C-BASE, the GALT score significant predictors of process skills and understanding physical science concepts is reassuring. This finding should be just one indicator that the current admittance standards for teacher education in this state have merit.

Purposes of the Study

In this predictive study, the C-BASE Science score, ACT Science score, GALT score, and total number of college science courses completed were investigated as predictors of science process skills and physical science misconceptions. Also investigated were the level of formal operational reasoning, science process skills, and physical science misconceptions of preservice elementary teachers.

Significance of the Study

The cry "Crisis in Education" (The National Science Board, 1983) has resounded across the nation during the Eighties. More specifically, the studies of science education, science education institutions, and science educators (e.g., Gallagher & Yager, 1981; Helgelson, Blosser, & Howe, 1977; Hueftle, Rakow, & Welch, 1983;Stake & Easley, 1978; Harms & Yager, 1981; Mechling & Oliver, 1983a, 1983b, 1983c, 1983d) have led to labeling the Eighties the "Crisis in Science Education." The result was reform efforts from kindergarten through college.

The reform efforts included such movements as the effective schools research (e.g., Edmonds, 1979), the call for more rigorous general education requirements (Passow, 1984), the goal of science education being the production of scientifically and technologically literate citizens (Yager, 1984), an emphasis upon science process skills in elementary science curriculum ("An NSTA Position, 1982), new accreditation of public schools with an emphasis upon mastery of core competencies and key skills (e.g., Missouri Department, 1986), process skills as a standard for elementary science teachers as recommended by the National Science Teachers (NSTA)/National Accreditation of Teacher Education (NCATE) (Padilla, 1987), and admittance into teacher education programs based on a cut-off score on a criterion referenced test (Excellence in Education, 1985). An emphasis upon higher order thinking skills ensued. Critical thinking skills (Adler, 1983; Blosser, 1985; Boyer, 1983; National Science Board Commission, 1983), formal operational reasoning modes (Capie, Newton, Tobin, 1981; DeCarcer, Gabel, & Staver, 1978; Inhelder & Piaget, 1958; Lawson, 1982; Lawson, 1985; Linn, 1982), process skills (Burns, Okey, & Wise, 1985), resolution of science misconceptions (Lawrenz, 1986), and the use of analogical reasoning in overcoming science misconceptions (Clement & Brown, 1984) are essential abilities for success in advanced secondary school science and mathematics courses. Acquisition and utilization of thinking skills and processes are essential for functioning in the "Information Age Society" (Costa, 1989; Naisbitt, 1982; Peters & Waterman, 1982; Resnick & Klopfer, 1989; Tofler, 1980). Formal operational reasoning has been found to be a predictor of achievement in science and mathematics (Bitner, 1986, 1988a, 1988b, 1991; Hofstein & Mandler, 1985; Howe & Durr, 1982; Lawson, 1983; Lawson, Lawson, & Lawson, 1984) and critical thinking abilities (Bitner, 1988a, 1988b, 1991).

Method

Sample

The sample ($\underline{N}$ = 29) for this predictive study included one section of the course "Teaching Science in the Elementary School" in a midwestern university with a student enrollment of approximately 20,000. This university certified more teachers during 1989-1990 than any other institution in the State. The Teacher Education Program has an enrollment of approximately 2,500. Of those, approximately 1,200 are elementary education majors. For admittance into the Teacher Education Program, students must have completed 45 credit hours with a GPA of 2.4, an ACT composite of 20, and a C-BASE composite of 235. In the science area, students are required to complete an elementary science methods course plus three science courses.

The sample consisted of four males and 25 females. Twenty-seven subjects were seniors and two were graduates returning for teacher certification. On the average, the subjects were 23.1 years of age ($\underline{SD}$ = 3.15, with a range of 21 - 34) and had a college GPA of 3.27 on a scale of 4.0 ($\underline{SD}$ = .43, with a range of 3.0 - 4.0). The number of college science courses completed ranged from 1 to 8 with a mean of 3.9. Of the sample, 20 (71%) had completed only one physical science course, 21 (75%) had taken only one earth science course, and 20 (71%) had completed one biological science course. Twenty-nine percent of the sample had completed two to four biological science courses. The subjects' average ACT composite score was 23.03 ($\underline{SD}$ = 2.61

with a range of 20 - 30) with a M = 23.82, SD = 4.12, and range of 16 - 32 on the Science sub-test. Their average C-BASE composite was 321 (SD = 45.46 with a range of 241 - 414) with a M = 323.52, SD = 62.70, and range of 215 - 413 on the science sub-test.

Instrumentation

Prior to admittance into the Teacher Education Program, the preservice elementary teachers had taken the ACT (American College Test) and C-BASE (College Basic Academic Subjects Examination). During the first two weeks of classes, 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 sample (N = 29). 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 six.

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 ($\underline{M}$ = .53). A range of .11 to .64 ($\underline{M}$ = .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 answered correctly 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 answering correctly items 24, 27, and 31 was 40, 50, and 36, respectively. Only 63% of the teachers answered correctly 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.

Statistical Analysis of Data Procedures

Frequencies and multiple regression programs from SPSS[x] (1986) were used to analyze the data. The stepwise regression analysis was used to determine how much variance in the science process skills in the TIPS II and the physical science misconceptions in the PST was accounted for by the independent variables. By using the stepwise regression method enter (forced), the analysis is primarily hierarchical (Cohen & Cohen, 1983). Tolerance (0.01), PIN (0.05), and POUT (0.10), the default criteria for the stepwise regression established by SPSS[x] (1986) were specified for the regression analysis. A 95% confidence level was established for determining significance of a regression coefficient (Achen, 1982).

Results

The scores on the science sub-tests of the ACT and C-BASE, the GALT score, and number of college science courses completed were found to be statistically significant predictors of science process skills on the TIPS II and physical science misconceptions on the PST.

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 genders.

Insert TABLE I about here

The distribution of the sample (N = 29) according to reasoning levels was 59% formal and 41% transitional (see TABLE I).

Insert TABLE II 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 III. For this sample, the lowest responding rate was 48% for item 27, an identifying and stating hypothesis objective.

Insert TABLE III on the TIPS II

Frequencies and Percents on the Physical Science Test

Fifty percent or less responded correctly to items 7, 19, 21, 22, 24, 25, 26, 27, 28, 29, 30, and 31. The mean score for the sample was 18.48 (SD = 4.59). The percent responding correctly to items 24, 27, and 31 was 24%, 41%, and 11%, respectively. Difficulty with item 24, 27, and 31 indicates a misconception about mass. Fifty-two percent responded correctly to item 17, another mass problem. The teachers had difficulties with items 7, 23, 25, and 28, indicating a misconception of electromagnetic phenomena/ electricity/light. Only 17% answered correctly item 26, which indicates a misconception about motion.

Insert TABLE IV about here

College Science Courses, ACT Science, C-BASE Science, and GALT: Predictors of TIPS II and PST

The scores on the science sub-tests of the ACT and C-BASE, the GALT score, and number of college science courses completed were found to be statistically significant predictors of science process skills on the TIPS II and physical science misconceptions on the PST (see TABLE V). The GALT score accounted for the largest percentage of the variance in process skills (TIPS II). The C-BASE science score accounted for the most variance in physical misconceptions (PST).

Insert TABLE V about here

Conclusions

Fifty-nine percent of the sample is functioning at the formal operational level. Correlational reasoning was the most difficult for this sample, a result previously reported by Bitner (1991).

Overall, the preservice elementary teachers performed well on the TIPS II. The males performed better that the females. Item 27, an identifying and stating hypothesis objective, seemed to present the most difficulty for this sample.

The results of the PST seemed to indicate misconceptions of physical science concepts. This sample had some of the same problems as a sample of inservice elementary teachers (Lawrenz, 1986). The majority of problems related to misconceptions of mass, motion, and electromagnetic phenomena/electricity/light.

The number of college science courses completed, science sub-tests on the ACT and C-BASE, and the GALT score were all significant predictors of science process skills and physical science misconceptions. It was anticipated that the GALT would contribute the most variance to process skills since the criterion-related reliability between the GALT and TIPS II was found to be .71. The C-BASE contributed the most variance in understanding physical science concepts. Perhaps this is attributable to the C-BASE's emphasis upon reasoning competencies.

Finding the number of college science courses, science sub-tests on the ACT and C-BASE, the GALT score significant predictors of process skills and understanding physical science concepts is reassuring. This finding should be just one indicator that the current admittance standards for teacher education programs in this state have merit. To verify these results, the study will be replicated with a larger sample.

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Table I

A Comparison of Means, Standard Deviations, and Item Difficulty on the GALT for the Sample (N=29)

Reasoning Ability	Male (n = 4)			Female (n = 25)			Total (N = 29)		
	M	SD	%	M	SD	%	M	SD	%
Conservation	2.00	.00	100	1.80	.42	90	1.83	.38	92
Item 1	1.00	.00	100	.92	.28	92	.93	.26	93
Item 4	1.00	.00	100	.88	.33	88	.90	.31	90
Proportionality	2.00	.00	100	1.36	.64	68	1.45	.63	73
Item 8	1.00	.00	100	.84	.37	84	.86	.35	86
Item 9	1.00	.00	100	.52	.51	52	.59	.50	59
Controlling Variables	1.50	1.00	75	1.40	.71	70	1.41	.73	71
Item 11	.75	.50	75	.52	.46	72	.72	.46	72
Item 13	.75	.50	75	.68	.48	68	.69	.47	69
Probability	1.50	1.00	75	1.60	.71	80	1.59	.73	79
Item 15	.75	.50	75	.80	.41	80	.79	.41	79
Item 16	.75	.50	75	.80	.41	80	.79	.41	79
Correlational	.75	.96	38	.60	.87	28	.62	.86	29
Item 17	.50	.58	50	.32	.48	32	.35	.48	34
Item 18	.25	.50	25	.24	.44	24	.24	.44	24
Combinatorial	1.50	.58	75	1.68	.48	86	1.66	.43	85
Item 19	1.00	.00	100	.92	.28	92	.93	.26	93
Item 20	.50	.58	50	.80	.41	80	.76	.44	76
GALT Total	9.25	2.06		8.44	2.40		8.55	2.34	

Table II

Levels of Reasoning on the GALT (N = 29)

	Reasoning Level					
Group	**Formal[a]**		**Transitional[b]**		**Concrete[c]**	
	N	**%**	**N**	**%**	**N**	**%**
Male (n = 4)	3	75	1	25	0	0
Female (n = 25)	14	56	11	44	0	0
Total (N = 29)	17	59	12	41	0	0

[a]Score = 8-12 (M = 10.24, SD = 1.93)

[b]Score = 5-7 (M = 6.17, SD = .72)

[c]Score = 0-4

TABLE III

Frequency and Percent on TIPS II for Sample (N=29)

Objectives/Items	Male (n = 4) F	Male (n = 4) %	Female (n= 25) F	Female (n= 25) %	Total(N = 29) F	Total(N = 29) %
Identifying Variables		79		75		76
1	4	100	21	84	25	86
3	4	100	24	96	28	97
13	4	100	16	64	20	69
14	3	75	19	76	22	76
15	3	75	13	52	16	55
18	3	75	17	68	20	69
19	3	75	19	76	22	76
20	3	75	17	68	20	69
30	3	75	19	76	22	76
31	3	75	23	92	26	90
32	2	50	21	84	23	79
36	[illegible]	75	16	67	19	68
Identifying and Stating Hypothesis		86		84		84
4	3	75	23	92	26	90
6	4	100	17	68	21	72
8	4	100	22	88	26	90
12	4	100	21	84	25	86
16	3	75	21	84	24	83
17	4	100	25	100	29	100
27	2	50	11	48	13	48
29	4	100	25	100	29	100
35	3	75	22	88	25	86
Operationally Defining		88		88		88
2	2	50	18	72	20	69
7	4	100	22	88	26	90
22	4	100	24	96	28	97
23	3	75	20	80	23	79
26	4	100	24	96	28	97
33	4	100	24	96	28	97
Designing Investigations		100		97		98
10	4	100	25	100	29	100
21	4	100	23	92	27	93
24	4	100	25	100	29	100
Graphing and Interpreting Data		100		89		91
5	4	100	21	84	25	86
9	4	100	25	100	29	100
11	4	100	24	96	28	97
25	4	100	23	92	27	93
28	4	100	24	96	28	97
34	4	100	17	68	21	72
Mean		31.50		30.08		30.28
Standard Deviation		5.45		4.80		4.82

Table IV

Frequency and Percent on the Physical Science Test (N=29)

Item	Male (n=4)		Female (n=25)		Total(N=29)	
	F	%	F	%	F	%
1-Atoms	4	100	23	92	27	93
2-Balances	3	75	21	84	24	83
3-Weights	4	100	22	88	26	90
4-Temperature	4	100	23	92	27	93
5-Hypothesis	4	100	23	92	27	93
6-Reflection	4	100	21	84	25	86
7-Magnetic Field	2	50	4	17	6	21
8-Voltage	0	0	19	76	19	66
9-Lens	4	100	23	92	27	93
10-Combustion	4	100	16	64	30	69
11-Path	3	75	14	56	17	59
12-Density	3	75	19	76	22	76
13-Evolution Star	4	100	19	76	23	79
14-Star	4	100	22	88	26	90
15-Heat	4	100	18	72	22	76
16-Chemical Bonds	3	75	19	76	22	76
17-Mass	4	100	11	44	15	52
18-Crystals	3	75	19	76	22	76
19-Particles	3	75	10	40	13	45
20-Mixture	3	75	12	50	15	54
21-Temperature Scales	2	50	12	48	14	48
22-Speed	2	50	11	44	13	45
23-Electrical Charge	4	100	16	64	20	69
24-Gas Mass	3	75	4	16	7	24
25-Electromagnetic	1	25	2	8	3	10
26-Motion	1	25	4	16	5	17
27-Mass Earth	4	100	8	32	12	41
28-Light	0	0	6	24	6	21
29-Chemical Reaction	2	50	12	48	14	48
30-Atoms	3	75	11	44	14	48
31-Mass	1	25	2	8	3	11
Mean	22.50		17.84		18.48	
Standard Deviation	4.04		4.40		4.59	

TABLE V

College Science Courses, ACT Science, C-BASE Science, and GALT: Predictors of TIPS II and PST Scores

	Process Skills TIPS II			Misconceptions PST		
Step	Predictors	R^2	F	Predictors	R^2	F
1	GALT	.40	17.85**	C-Base Science	.42	19.19**
2	C-Base Science	.52	12.81**	Science Courses	.51	13.45**
3	Science Courses	.53	6.82*	GALT	.52	6.51*
4	ACT Science	.53	6.82*	ACT Science	.52	6.51*

Note. When identical R^2 values are given for the regression equation, it indicates that those variables shared the reported variance.

**$p < .0001$

*$p < .001$