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AUTHOR	McMurray, Mary Anne; And Others
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ABSTRACT

The study was conducted to gain some insight regarding whether the nature of critical thinking skills in biology appears to be different than the nature of more general critical thinking skills. The study falls within the context of previous studies (e.g., research by J. P. Guilford, 1967; and M. Rokeach, 1973) that used empirical methods to delineate constructs. Subjects were 47 undergraduate students enrolled in an introductory biology course at either a public university or a smaller private university in the southern United States. The subjects completed a measure of critical thinking skills in biology, the Watson-Glaser Critical Thinking Appraisal, the Group Embedded Figures Test, and the American College Tests. The results suggest that critical thinking in biology does involve some domain-specific skills. Critical thinking might best be measured with content-specific tests when interventions are being evaluated, and critical thinking skills may not necessarily generalize across content domains. Two data tables are included. (Author/SLD)

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IDENTIFYING DOMAIN--SPECIFIC ASPECTS OF CRITICAL THINKING ABILIT`` IN SOLVING PROBLEMS IN BIOLOGY

Mary Anne McMur_ay Bruce Thompson Paul Beisenherz

University of New Orleans 70148

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ABSTRACT

The study was conducted to gain some insight regarding whether the nature of critical thinking skills in biology appears to be different than the nature of more general critical thinking skills. The study falls within the context of previous "The Nature of..." studies (e.g., Guilford, 1967; Rokeach, 1973) that employed empirical methods to delineate constructs. The subjects completed a measure of critical thinking skills in biology, the Watson-Glaser Critical Thinking Appraisal, the Group Embedded Figures Test, and the ACT. This result suggests that critical thinking in biology does involve some domain specific skills.

Democracy is not the most efficient form of government a group of people might chose, but it is a form which recognizes the freedom of individuals to make choices. The successful implementation of democracy requires individuals to be able to make informed and reasoned decisions to establish those policies that best realize the values espoused by the populace. Thus, as Thompson and Melancon (1987, p. 1223) note, "Educators have come to realize that teaching critical thinking skills is an essential school function."

The responsibility for teaching critical thinking skills falls to teachers in various disciplines, but as the development of technology accelerates at increasing rates, citizenship increasingly involves at least some complex biological "relationships that only the life science teacher has either the competence or the opportunity to deal with in the classroom" (Hickman, 1982, p. 358). Similarly, Linn (1987) noted that the report to the National Science Board, Educating Americans for the 21st Century,

> revealed that the instruction students receive in science does not prepare them to cope with the problems they will face and argued that students need to learn the "new basics"--the thinking skills required for choosing among new medical treatments, for example, or pursuing careers in technologically rich environments, or investing wisely.

But regardless of on whom the responsibility for teaching critical thinking devolves, it is clear that efforts to teach critical thinking do presume the ability to diagnose needs and to measure intervention effects, and measurement, in turn, presumes the ability to define the construct being measured. The effort to define critical thinking ability has received a good deal of recent attention (Sternberg, 1986, p. 189). Kitchener (1983) suggests that various traditions of thought underlie conceptualizations of critical thinking ability. One group (e.g., Ennis, 1985) emphasizes logic and the hypothetico-deductive method, while other theorists (e.g., Glasser, 1985; Skinner, 1976) relate critical thinking to problem solving and a general process of inquiry. Still another group of theorists (cf. Abo El-Nasser, 1979) emphasizes individual skills, or "what might be called prerequisite conditions of critical thinking" (p. 27). Recent views emphasize the importance of critical thinking in a "strong sense" (Paul, 1986); these views presume the importance of the ability to reason dialectally and to not be limited to single frames of reference when thinking.

Notwithstanding recent progress in delineating a construct of critical thinking, the nature of critical thinking remains somewhat unclear. The purpose of the present inquiry was to conduct an empirical investigation designed with the potential to help identify the nature of critical thinking skills in biology. The inquiry was conducted in the tradition of studies such as those of Guilford (1967) and of Rokeach (1973). Specifically, the study was conducted to gain some insight regarding whether the nature of critical thinking skills in biology appears to be different than the nature of more general critical thinking skills.

Method

Subjects

The subjects in the present study were 47 undergraduate students enrolled in introductory biology courses at either a public university (n=20) or a smaller private university (n=27) located in the same city. Both universities were located in the southern United States. The subjects completed the study's measure of critical thinking ability in biology at the end of the semester.

Since only students who voluntarily agreed to participate in the study were included as subjects in the study, it was particularly important to confirm that our subjects were representative of the population from which the subjects were drawn. Various analyses were conducted for this purpose. Exactly the same percentage (36%) of our 47 subjects were males as were male in the group of the remaining 290 biology students who did not participate in the study. The average grade placement (1.64; SD=0.96; "1" = freshman, "2" = sophomore, etc.) of our 47 students was exactly the same (1.64, SD=1.05) as that of the 290 students who did not participate. The average ACT Composite scores of our subjects was very slightly lower (16.96; SD=5.50) than the same scores (17.73; SD=4.94) of the students who did not participate in the study.

These results suggest that our final sample of subjects was representative of the larger group from which the 47 students were drawn. It is also noteworthy that the mean ACT score was only slightly lower that the typical national average on the test, which tends to be about 18 across test administrations. This last comparison has important implications regarding the generalizability of our results.

Instrumentation

The measure of critical thinking skills in biology, the Test of Critical Thinking in Biology (TCTB), consisted of 52 items. These items were selected from an initial item pool consisting of 75 items, almost all of which were selected from the items made available by Donovan and Allen (1983). These initial 75 items were administered in a pilot study to 72 students not in the pool of 337 subjects from which the results for the 47 students reported here were derived. Based on classical measurement theory item difficulty and discrimination coefficients (Thompson & Levitov, 1985), 52 items with the most desirable measurement characteristics were retained for future use. The number of items in each topic area were, respectively: (a) Protein Synthesis and Enzymes, 11 items; (b) Diffusion and Osmosis, 7 items; (c) Respiration, 12 items; (d) Photosynthesis, 4 items; (e) Cells and Cell Division, 10 items; (f) general Biological Information, 5 items; and (g) Ecological Interactions, 3 items. The alpha reliability coefficient for the data collected from the 72 pilot-study subjects on the 52 items was 0.83.

The 47 subjects completed the 52-item TCTB both at the beginning of a semester ("TCTB Pre") and again at the end of the semester ("TCTB Post"). The subjects also completed the Critical Thinking Appraisal (CTA), a well-known measure of general critical thinking ability developed by Watson and Glaser (1980), at semester's end. Since field independence measures a cognitive style preference to be analytical (Melancon & Thompson, 1987), to further explore the nature of critical thinking skills in biology, at the end of the semester the subjects completed a well-known measure of field independence, the Group Embedded Figures Test (GEFT) (Witkin, Oltman, Raskin & Karp, 1971). Finally, data were available for 23 subjects on both ACT composite scores and scores on the natural science component of the test.

Results

The purpose of the present study was to determine whether the nature of critical thinking skills in biology appears to be different than the nature of more general critical thinking skills. Residualization or covariance adjustment procedures were employed to address the study's primary research question. Scores from the Watson-Glaser Critical Thinking Appraisal posttest were employed as the covariate or residualizing variable.

CTA posttest score variance was removed from variance in the 52 items on the Test of Critical Thinking in Biology (TCTB), from variance in scores on each of the seven TCTB topical subtests, and from variance in total scores on the TCTB. The residualized scores of the 47 subjects were then correlated with ACT Composite scores, scores on the Natural Science subtest of the ACT, scores on the Group Embedded Figures Test (GEFT), and scores on the pretest administration of the Watson-Glaser Critical Thinking Appraisal (CTA). These results are presented in Table 1.

INSERT TABLE 1 ABOUT HERE.

Discussion

The present study was conducted to gain some insight regarding whether the nature of critical thinking skills in biology appears to be different than the nature of more general critical thinking skills. The results reported in Table 1 can be interpreted to address this research question. However, some preliminary comments warrant initial discussion.

Statistical procedures referred to as partialing, residualization, or covariance adjusting, must be used with caution (Thompson, 1988). Among other assumptions, these methods assume very reliable measurement of the covariate. Two analyses in the present study are relevant to evaluating the measurement integrity of the covariate, scores on the Test of Critical Thinking in Biology (TCTB) posttest. First, the Cronbach's alpha coefficient for the TCTB posttest for the 47 subjects was 0.83, the same value obtained in the pilot test with these 52 items and a different group of 72 subjects. This result suggests that TCTB scores are reasonably reliable.

Second, the correlation coefficients between residualized TCTB scores and Watson-Glaser Critical Thinking Appraisal (CTA) pretest scores are relevant to evaluating the integrity of scores residualized by data from the CTA posttest. Logically, if the CTA provides reliable and valid data, then these coefficients, reported in the last column of Table 1, should generally approach zero. There should be little variance in TCTB scores, once residualized by CTA posttest scores, that can be associated with CTA pretest scores, if the two CTA administrations yield comparable scores for subjects. In general, this expectation was reasonably well met.

With regard to the study's primary research question, the results presented in Table 1 suggest that TCTB scores, after the scores are residualized by variance in CTA posttest data, are most strongly associated with scores on the Natural Science scale of the ACT. This pattern tends to be charactersitic of residualized scores on TCTB items, topical subtests, and total scores. Since TCTB total scores should theoretically be more reliable than either item scores or topical subtest scores, perhaps total score results should be most emphasized. As noted in Table 1, TCTB total scores, once residualized by Watson-Glaser CTA posttest scores, share about 22.7% variance in common with ACT Natural Science scores. This pattern becomes even more apparent when the residualized correlation coefficients reported in Table 1 are compared with zero-order bovariate correlation coefficients, as presented in Table 2.

INSERT TABLE 2 ABOUT HERE.

As reported in Table 2, TCTB scores are most highly related (squared r=46.2%) with ACT Science scores prior to residualization of ACT scores by CTA posttest scores. Furthermore, as reported in the "% change r squared" row of Table 2, the residualization process removes more than 80% of the common variance between TCTB scores and all the predictor variables except ACT Science scores, for which residualization removes 50.9% of the common variance. Even after residualization, ACT Science scores have the most variance in common (22.7%) with what is left of TCTB scores.

This result suggests that critical thinking in biology, as reflected in TCTB scores, does involve some domain specific skills. The result suggests that critical thinking might best be measured with content-specific tests when interventions are being evaluated. Furthermore, the result suggests that critical thinking skills may not necessarily generalize across content domains.

Obviously, no one study can resolve questions regarding the nature of critical thinking. All studies are subject to limitations. For example, sample size in the present study means that results must be interpreted with caution, notwithstanding the use of empirical analyses conducted to evaluate the representativeness of the sample. Still, the results suggest that some critical thinking skills are partially domain-specific, and must be measured from a perspective which honors this reality.

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Table 1
Bivariate Correlation Coefficients Between TCTB Scores, Residualized Using CTA Posttest Scores, and Selected Predictors

Criterion Variable		Predictor Variable							
		ACT Comp		ACT Science		GEFT		WGCTA Pre	
TCTB Item	Topic	r	sq r	r	sq r	r	sq r	r	sq r
47	e	.54	29.1%	.60	35.5%	.15	2.3%	.04	.2%
18	a	.18	3.2%	.52	26.8%	.25	6.2%	.14	2.1%
42	d	.03	.1%	.46	21.2%	.18	3.4%	.06	.3%
35	g	-.03	.1%	.44	19.7%	.11	1.2%	.08	.6%
7	b	.24	6.0%	.43	18.2%	.00	.0%	.08	.6%
31	e	-.25	6.0%	-.40	15.8%	-.14	2.1%	-.17	3.0%
27	c	.32	10.4%	.40	15.7%	-.08	.6%	.14	2.0%
8	c	.14	2.0%	.39	15.4%	.12	1.4%	.01	.0%
10	a	.00	.0%	.36	13.2%	.11	1.3%	.11	1.2%
41	d	.40	15.8%	.36	13.1%	.06	.3%	.21	4.5%
9	d	.36	13.3%	.36	12.8%	.01	.0%	.10	1.0%
28	c	.11	1.3%	.34	11.8%	.11	1.2%	.24	5.7%
44	e	.05	.2%	.34	11.4%	-.14	2.1%	.14	2.1%
20	a	.30	8.8%	.33	10.6%	.18	3.4%	.01	.0%
2	a	.28	7.7%	.32	10.4%	.23	5.2%	.22	4.8%
36	c	-.07	.5%	-.32	10.1%	-.34	11.6%	.14	2.1%
51	g	.22	4.7%	.31	9.4%	.27	7.4%	.15	2.3%
38	b	.06	.4%	.29	8.2%	-.06	.3%	.06	.4%
30	c	.41	17.2%	.28	7.9%	-.01	.0%	.01	.0%
25	b	-.08	.6%	.26	7.0%	.08	.7%	-.01	.0%
21	a	.30	8.9%	.26	6.7%	.09	.9%	.18	3.1%
3	a	.33	11.1%	.25	6.4%	-.03	.1%	.22	4.9%
13	e	.19	3.5%	.22	5.0%	.07	.4%	.07	.5%
5	b	.22	5.0%	.22	4.8%	.23	5.3%	.09	.7%
32	e	.01	.0%	.22	4.8%	.20	4.0%	-.01	.0%
4	a	.23	5.1%	.21	4.4%	.10	1.1%	-.01	.0%
43	e	-.14	2.0%	-.21	4.3%	-.11	1.3%	.06	.4%
50	g	-.03	.1%	.20	4.1%	.15	2.2%	.08	.7%
37	a	.21	4.4%	.19	3.5%	.12	1.4%	.09	.8%
45	e	-.04	.2%	-.17	3.0%	-.03	.1%	.18	3.1%
16	f	-.06	.3%	.17	3.0%	.04	.1%	.01	.0%
14	e	-.07	.5%	.17	3.0%	-.13	1.8%	.14	2.0%
34	f	.22	4.8%	.17	2.9%	-.02	.0%	.09	.9%
52	c	.11	1.3%	.17	2.9%	-.08	.6%	.11	1.3%
33	f	.37	13.6%	.16	2.5%	-.01	.0%	.07	.5%
26	c	-.09	.9%	.12	1.5%	.19	3.7%	.00	.0%
46	e	.34	11.4%	.12	1.4%	.19	3.7%	.06	.3%
17	c	-.19	3.6%	.11	1.3%	-.01	.0%	-.13	1.6%
22	a	.13	1.7%	.09	.6%	-.09	.8%	.09	.8%
49	f	-.24	5.9%	-.08	.6%	.09	.8%	.04	.1%
11	c	-.14	2.0%	.06	.4%	-.20	4.0%	.10	1.0%
40	c	-.17	2.8%	-.06	.4%	-.10	1.1%	-.04	.2%
6	b	-.18	3.1%	-.06	.4%	-.05	.3%	.01	.0%
24	b	-.09	.8%	-.05	.2%	.03	.1%	.01	.0%
15	e	-.15	2.2%	-.03	.1%	.11	1.1%	.00	.0%
23	b	.06	.3%	-.03	.1%	-.12	1.5%	-.03	.1%

19	a	-.09	.8%	-.03	.1%	-.05	.3%	.14	2.1%
39	c	-.10	.9%	-.02	.0%	.21	4.5%	-.06	.3%
12	d	.05	.3%	.01	.0%	.10	1.0%	.10	1.0%
29	c	.07	.5%	-.01	.0%	-.12	1.5%	.27	7.5%
1	a	-.23	5.2%	-.01	.0%	.12	1.3%	-.15	2.4%
48	f	-.08	.6%	-.01	.0%	.02	.0%	-.02	.0%
Mean		.08	4.4%	.16	7.0%	.04	1.8%	.07	1.3%
SD		.20	5.6%	.21	7.6%	.13	2.2%	.09	1.6%
TCTB Test Topic									
Photosynthesis (d)		.33	11.2%	.48	22.7%	.17	2.9%	.23	5.3%
Proteins (a)		.34	11.5%	.46	21.4%	.21	4.4%	.22	4.8%
Ecology (g)		.09	.7%	.40	15.8%	.25	6.4%	.15	2.2%
Diffusion (b)		.07	.5%	.37	13.9%	.05	.2%	.07	.5%
Respiration (c)		.11	1.2%	.32	10.4%	-.07	.5%	.21	4.3%
General Biology (f)		.13	1.8%	.17	3.0%	.04	.1%	.08	6%
Cells (e)		.09	.7%	.14	2.0%	.02	.0%	.13	1.7%
TCTB Total Score		.25	6.0%	.48	22.7%	.13	1.7%	.26	6.7%

Note. The "Topic Covered" designations correspond with those mentioned in the narrative. For example, item 47 measures "e", Cells. n's for all coefficients were 47, with the exception of coefficients involving ACT scores, for which the n's were 23.

Table 2
Zero-Order and Residualized r's Between TCTB Scores and Selected Predictor Variables

	ACT Comp	ACT Sci	GEFT	WGCTA Pre
Zero-Order r	0.67	0.68	0.38	0.64
	44.9%	46.2%	14.4%	41.0%
Residualized r	0.25	0.48	0.13	0.26
	6.0%	22.7%	1.7%	6.7%
% change r squared	86.6%	50.9%	88.2%	83.6%

Note. Squared correlation coefficients are presented as percentages.