A Mixed-Methods Study Of Undergraduate Dispositions Toward Thinking Critically About Biotechnology

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Abstract

The purpose of this mixed-methods study was two-fold: (1) to evaluate the ability of students to think critically about biotechnology after being exposed to instruction designed to enhance critical thinking skills and (2) to explore the relationship between academic achievement status, gender and abilities to think critically. Guided by theoretical frameworks for critical thinking in specific disciplines, this study utilized a mixed methodology combining a descriptive survey with a qualitative focus group technique. Analysis of the focus group data employed a content analysis approach and uncovered several key findings. A key implication of this study is the finding that disposition to think critically did increase from the beginning to the end of the course for all students. Honors and non-honors students applied different critical thinking constructs more frequently. Student respondents in the study not only increased in overall disposition to think critically, but were able to apply what they learned to the specific content areas. From an agricultural education standpoint, the implication is that teaching for critical thinking can be an effective way to enhance thinking abilities of all students in specific content areas when critical thinking instructional techniques are used appropriately.

Introduction

Two years ago, Rudd, Baker and Hoover (2000) argued for greater study of critical thinking by agricultural educators and researchers, citing lower than expected scores for disposition to think critically among agricultural students, as well as the role critical thinking

plays in making connections between areas of inquiry or drawing of inferences that can be utilized by faculty members in college classrooms (p. 2).

At the same time, the controversy over genetically engineered food in Europe and more recently in the U.S. has prompted many agricultural educators and scientists to begin engaging in more open dialogue with the public in order to provide education as to the safety and benefits of this new technology. According to the National Academy of Science (NAS), it is imperative "to develop a genetically literate public that understands basic biological research, understands elements of the personal and health implications of genetics, and participates effectively in public policy issues involving genetic information" (Armstrong, 2000). But, given the cross cutting, interdisciplinary nature of the issues involved, the problem as to how to educate our students to understand and be able to address biotechnology issues has so far proven to be a challenge.

One of the difficulties associated with attempting to develop greater understanding of biotechnology among our students is that the science is relatively sophisticated, rapidly changing, and often difficult for students to grasp. Further complicating the educational process is the fact that studies have suggested that most consumers get their information on biotechnology from the media (Hoban, 1998). Indeed, studies indicate that most of the public's information about biotechnology comes from the mass media, even though their level of trust in what they learn is relatively low (Hallman & Metcalf, 1995). This is true of agricultural educators as well. In a study of teachers of agriculture from three southern states, Iverson (1998) found that the major source for information about biotechnology was the mass media, primarily newspapers. On the other hand, respondents felt their most *trusted* source of information about biotechnology was the land grant university.

Despite these challenges, some university-level agricultural educators have begun teaching courses solely focused on biotechnology and/or to include it as a course topic in agri-sciences curricula. Arguably, the ultimate objective of such educational efforts among agricultural institutions of higher learning is to enhance understanding and acceptance of food biotechnology. But how can we determine whether or not these objectives are actually being achieved? As agricultural educators, we may have the educational objective of wanting our students to know more about the science associated with biotechnology, its benefits, perceived risks, and attendant potential social issues. But while we can measure knowledge acquisition based on exposure to information, that does not necessarily inform us of actionable outcomes associated with values, belief systems, attitude formation, and change.

The literature has consistently shown that simple exposure to information will not necessarily influence knowledge, attitude or change behavior (Rogers, 1995; Salwen & Sacks, 1997; Goldberg, Fishbein & Middlestadt, 1997). As nationally known biotechnology educator Thomas Zinnen (2000) has pointed out there is a distinction that needs to be made between individual understanding of biotechnology and acceptance of biotechnology-derived products. For one to lead to the other may require higher order thinking and evaluation that operates beyond mere exposure to factual information in the classroom or elsewhere. Therefore, it may not be enough to produce educational curricula and conduct instruction that contain balanced, fact-based, objective information in an attempt to raise awareness and enhance knowledge

acquisition. It may be equally important to determine how to develop such instruction so as to specifically focus on enhancing a student's ability to ***think and reason critically*** about biotechnology. This would have the added benefit of ensuring that our future graduates in the food and agricultural sciences are equipped with strong reasoning and thinking skills that will help them act, communicate and educate effectively about this important topic.

Huitt (1998) argued that critical thinking is a *process* that may best be developed when students learn in connection with a specific domain of knowledge, through which they can come to pursue the thinking and reasoning process to some actionable conclusion or outcome. But, while researchers have often focused on teaching critical thinking and its components as a set of skills or standards, few investigators have focused their study on the development of critical thinking within a specific content area or discipline (Carr, 1990; Hichey, 1990; Mertes, 1991). As such, the present study sought to focus on the study of agricultural educators' use of critical thinking, "a reasoned, purposive, and introspective approach to solving problems or addressing questions with incomplete evidence and information and for which an incontrovertible solution is unlikely" (Rudd, Baker & Hoover, 2000, p. 5), as an instructional tool for teaching students to think critically about food biotechnology.

Theoretical Framework

Over the last several decades, critical thinking has been discussed and contemplated in educational circles. Many definitions of critical thinking have been offered. In 1991, Pascarella and Terenzini compiled several definitions to say that critical thinking "typically involves the individual's ability to do some or all of the following: identify central issues and assumptions in an argument, recognize important relationships, make correct inferences from data, deduce conclusions from information or data provided, interpret whether conclusions are warranted on the basis of the data given, and evaluate evidence or authority (p. 118)."

Critical thinking involves the formation of logical inferences (Simon & Kaplan, 1989). Some scholars and educators erroneously assume critical thinking to be higher order thinking or cognitive processing (Paul, 1994). Critical thinking can be set apart from problem solving (Hedges, 1991) in that problem solving is a linear process of evaluation, while critical thinking is an comprehensive set of abilities allowing the inquirer to properly facilitate each stage of the linear problem-solving process.

According to Chafee (1988) critical thinking is "our active, purposeful, and organized efforts to make sense of our world by carefully examining our thinking, and the thinking of others, in order to clarify and improve our understanding" (p.29). According to Halpern (1989) critical thinking is "thinking that is purposeful, reasoned and goal directed. It is the kind of thinking involved, in solving problems, formulating inferences, calculating likelihoods, and making decisions" (p. 5). Simply put, critical thinking is the "reasonable and reflective thinking that is focused upon deciding what to believe or do" (Norris & Ennis, 1989, p. 18).

Skills and Dispositions Toward Critical Thinking

In 1933, Dewey contended that three attitudes were necessary to constitute reflective action (critical thinking); open mindedness, responsibility, and wholeheartedness. An individual

was open-minded if they listened to more than one side of any issue. Responsibility referred to carefully evaluating the consequences of a potential action, and wholeheartedness demanded that critical thinkers be intentional in their search for the truth (Cheak, 1999).

In developing the widely used Watson-Glaser Critical Thinking Appraisal, Glaser (1941) defined critical thinking as the "(1) attitude of being disposed to consider in a thoughtful way the problems and subjects that come within the range of one's experiences, (2) knowledge of the methods of logical inquiry and reasoning and (3) some skill in applying those methods" (p. 5-6). Later, in 1997, Taube reported statistical and empirical evidence of skills and dispositions, two distinct factors of critical thinking.

Experts continue to agree that critical thinking includes the dimensions of skill and disposition (Dewey 1933; Norris and Ennis 1989). In 1990, Facione and his group of experts went a step further. They identified a set of specific skills and sub-skills for the skill dimension and a specific set of attitudes for the disposition dimension (Facione 1990).

Facione (2001) developed the CCTDI (California Critical Thinking Disposition Inventory), in order to measure these skills, sub-skills and attitudes. The constructs used are Truth-Seeking, Open-mindedness, Analyticity, Systematicity, Self-confidence, Inquisitiveness, and Maturity (Facione, Facione et al. 2001). The following construct descriptions are from the CCTDI test manual (Facione, Facione, & Giancarlo, 1996).

1. *Analyticity* targets the disposition of being alert to potentially problematic situations and anticipating possible results or consequences.
2. *Self-confidence* refers to the level of trust one places in one's own reasoning process.
3. *Inquisitiveness* is innate curiousness about acquiring information and which motivates the message recipient to learn more.
4. *Maturity* addresses cognitive Maturity and mature thinkers are disposed to approach problems, inquiry and decision making realizing that some situations have more than one plausible option and that decisions must sometimes be made without the benefit of having all the relevant information about the situation.
5. *Open-mindedness* addresses the state of respecting the right of others with differing opinions.
6. *Systemacity* targets the disposition to being organized, orderly, focused and diligent in seeking information.
7. *Truth-seeking* describes thinkers who are eager to seek the truth even if the results do not support one's own interests or preconceived opinions.

Critical Thinking in Specific Disciplines

While critical thinking is a valuable skill that, once learned, can be applied in many different disciplines, researchers have contended that there is a need to think critically within specific disciplines. According to Glaser, critical thinking is, in part, "attitude of being disposed to consider in a thoughtful way the problems and subjects that come within the range of one's experiences (1941, p. 5-6).

Ennis advocates contextual, domain, or subject specific critical thinking for several reasons. First, background knowledge is necessary for making justified critical thinking judgments. Second, critical thinking varies from discipline to discipline and, third, a full understanding of a discipline requires the ability to think critically in the discipline (Ennis 1990).

> (Halliday 2000) argues that critical thinking is to be used in the context of specific disciplines. He quotes Dunne and Morgan from their article in *Irish Educational Studies*. "Critical thinking is best developed through an engagement with different areas of knowledge rather than as an autonomous skill to be taught in itself. It is through cutting its teeth on actual topics, themes, an issues and problems as these arise within diverse content domains that thinking can acquire the kind of differentiation subtlety and sense of relevance that help to make it truly critical" (Dunne and Morgan, 1995, p. 115).

According to Guthrie, Alao & Rinehart (1997), there is a need to situate literacy learning, such as critical thinking skills, within content areas in order to drive learning and increase both literacy ability and knowledge in the content area.

Predictors and Correlates of Critical Thinking Skills

Various potential predictors of critical thinking skills have been studied. The majority of the studies in the literature show age as having no significant difference or no relationship to critical thinking (Cillizza 1970; Feely 1975; Facione 1990; Facione 1991; Claytor 1997; Jenkins 1998; Rodriquez 2000; Rudd, Baker et al. 2000; Thompson 2001). The role of gender has not been as conclusive. Some studies have shown gender to not be related to critical thinking skills (Claytor 1997), while other studies have found a significant relationship between gender and critical thinking skills (Rudd, Baker et al. 2000; Walsh 1996; (Wilson 1989).

While the role of gender in critical thinking is unclear, academic achievement status, as exemplified, for example, by high GPA scores, has been shown to be related to critical thinking. Giancarlo and Facione (2001) found that GPA was significantly correlated with four of the CCTDI scales: Openmindedness, Analycity, Systemacity and Maturity. GPA was not found to be significantly correlated, however, with Truth seeking, Confidence or Inquisitiveness. Additionally, SAT scores have consistently been shown to be significantly correlated with scores on critical thinking instruments (Facione & Facione, 1992; Erwin, 1996; Jacobs, 1995; Frisby, 1992) as have ACT scores (Mines et al., 1990; King et al., 1990). By extension, it could be assumed that other hallmarks of high academic achievement, for example, selection as an undergraduate honors program participant, might be similarly related to CCTDI scores.

Purpose and Objectives

This study was conducted under the auspices of a USDA Higher Education Challenge Grant project. The grant was awarded for the development of an instructional model and skills assessment instrument to measure critical thinking skills development in a discipline-specific context within agri-science education, in this case, an undergraduate course in biotechnology taught through the agronomy department at a large land-grant university. The course under study was designed to focus on specific instructional techniques associated with critical thinking skills and sub-skills as identified by Facione (1991) and was offered by the same instructor with both a regular class and an undergraduate honors section. The criteria for selection for the honors program was based on a 3.9 high school academic grade point average (GPA) and a combined 1350 Scholastic Aptitude Test (SAT) score or a composite score of 30 on the American College Test (ACT). Thus, the assumption could be made that students in the honors section of this course would score higher on the CCTDI and be more successful in applying critical thinking constructs to thinking about the specific discipline area of biotechnology.

The purpose of this study was two-fold: (1) to evaluate the ability of students to think critically about biotechnology after being exposed to instruction designed to enhance critical thinking skills and (2) to explore the relationship between academic achievement status, gender and abilities to think critically.

The specific objectives of this study were to:

1. Describe the ability of students to apply critical thinking constructs to their perceptions of biotechnology and critical thinking.
2. Compare the dispositions and abilities to think critically of males vs. females.
3. Compare the dispositions and abilities to think critically of honors vs. non-honors students.

Methods/Procedures

The research design for this study utilized a mixed methodology combining a descriptive survey with a qualitative focus group technique. The population for this study was students (N=29) in an undergraduate class in plant biotechnology with concurrent honors and non-honors sections, taught in Spring 2002. To conduct the study, students were administered the California Critical Thinking Dispositional Inventory (CCTDI) a 75 item Likert scale with seven sub scale factors at the beginning and then again at the end of the course. Alpha reliability for the CCTDI has been extensively tested and evaluated; for the seven sub scales alpha reliability has been reported as ranging from .71 to .80; alpha reliability for the overall instrument has been reported at .91. To calculate the CCTDI score, the seven subscales indexes are first summed, and then weighted and an overall score is calculated. Overall CCTDI test scores can range from zero to 420.

In addition to the CCTDI, two focus groups with students in the class were conducted at the end of the semester, one with the honors section and one with the non-honors section. The focus groups began with questions about the background of each student. The rest of the protocol was developed in three sections: (1) Knowledge of and attitudes toward biotechnology, (2) Response to a set of three scenarios about implications of biotechnology, and (3) Dispositions

toward critical thinking. The protocol was reviewed by and expert panel of faculty in the Department of Agricultural Education and Communication for face and content validity. The focus groups were subsequently conducted by the researchers.

Analysis of the focus group data employed a content analysis approach, specified as a priori based on looking for students' ability to utilize Facione's seven constructs of critical thinking given as specified variables to determine a set of codes (Ary, 1996). After the focus groups were transcribed, six coders were given instructions on how to look through the transcripts for the seven constructs. The use of multiple observers (Ary, 1996) enhanced the probability that the interpretations were credible and verifiable. Once the transcripts were coded, they were analyzed for agreement between coders, and overall themes were identified.

Results/Findings

Results of the study indicated that 55.2% of the student respondents were female ($\underline{n}$ = 16) and 44.8% were male ($\underline{n}$ = 13); 67.9% (19) students were non-honors, while 32.1% (9) were honors section students (one student did not respond to this question). Overall CCTDI pre-test score (M=295, SD = 29.23) increased on the post-test (M = 306, SD = 28.36) for all respondents. Average CCTDI score for male students increased from 287 (SD= 38.31) to 304 (SD =31.58), while for females, score increased from 302 (SD=19.36) to 305 (SD =23.31). For students in the regular class section, CCTDI score increased from 295 (SD = 34.81) to 304 (NSD = 30.98), while for honors students, beginning CCTDI score (M = 300, SD = 14.68) increased to 307 (SD = 29.29) by the end of the course.

Table 1

Pre-test and Post-test CCTDI scores

	Pre-test scores			*Post-test scores*		
	M	*N*	*SD*	*M*	*N*	*SD*
Males	287	13	38.31	304	13	31.58
Females	302	16	19.36	305	16	23.31
Honors	300	9	14.68	307	9	29.29
Non-honors	295	19	34.81	304	19	30.98
Total	295	29	29.23	306	29	28.36

Results of the qualitative analysis of focus group findings indicated several common themes in terms of ability to apply critical thinking constructs in general and with respect to its use as an instructional technique in the course as follows:

Honors and non-honors students applied different critical thinking constructs more frequently.

Students in the non-honors focus group were more slightly more likely to apply such constructs as Inquisitiveness, Analycity and Confidence. For example, Inquisitiveness was displayed by one female student when she commented, "Phytoremediation; I am curious as to what real bananas taste like." In contrast, students in the honors section tended to apply Open-mindedness, Systemacity, Truth seeking and Maturity in addition to the other constructs. A male

honors student, when asked about labeling of GMO foods said, “I think it would produce unnecessary fears and they might start buying something else,” applying Analycity. Answering the same question, a female honors student said, “I think that is a tricky subject, people argue they have the right and that is a valid argument, but it is a pain, so I can't make a decision on it,” applying Analycity, Open-mindedness, and Maturity.

Table 2

Overall occurrence of critical thinking constructs in focus groups

(I=Inquisitiveness, O-Open-mindedness, A=Analycity, C=Confidence, T=Truth seeking, M=Maturity)

	I	O	A	S	C	T	M
Honors	30	47	57	33	17	26	30
Non-honors	31	33	67	16	19	16	15

Generally, these findings support Giancarlo and Facione’s (2001) findings that students with higher GPAs were more likely to apply Open-mindedness, Analycity, Systemacity, and Maturity, while there was no significant difference in CCTDI score for Truth seeking, Confidence or Inquisitiveness.

Females were more likely to apply critical thinking constructs in response to scenarios, while males were more likely to apply the constructs in response to general questions asked.

According to Tannen (1991), females are culturally socialized to build and maintain relationships through cooperation. In the focus groups, females tended to apply critical thinking constructs more frequently in response to the biotechnology scenarios in which the group worked together to present solutions or answers to a real-life situation. However, in response to general questions about biotechnology and critical thinking, males tended to apply critical thinking constructs more often.

Table 3

Occurrence of critical thinking constructs in response to different question types

	I	O	A	S	C	T	M
Males General questions	27	38	19	10	13	25	12
Females General questions	25	25	16	12	8	13	5
Males Scenarios	4	5	39	12	7	0	16
Females Scenarios	5	12	50	10	8	4	12

Honors students applied critical thinking constructs more frequently in discussing their perceptions of critical thinking. They seemed to be more cognizant of the critical thinking curriculum throughout the semester in the class.

One male in the honors focus group said, "It's hard to put a description on something you think you do everyday. You take in all the information you can before you make a decision. You kind of just assume you do it. First thing you hear you don't just jump on it, it's something you do everyday, I guess it's good to put a name to it – informed." Students in the non-honors section seemed less aware of the intentional critical thinking curriculum in the class. One male student seemed to believe that critical thinking was the natural way to consider biotechnology, saying, "I think you have to do it that way. You have to look into it to understand it. Most people do it anyway."

Table 4

Occurrence of critical thinking constructs in response to questions about critical thinking

	I	O	A	S	C	T	M
Honors	9	29	7	7	4	22	10
Non-honors	3	8	1	7	4	3	3

All students applied Systemacity comparably in response to different question types.

Sytemacity is defined as the disposition to being organized, orderly, focused and diligent in seeking information. Throughout the semester, students were taught strategies for organizing information and seeking information methodically. As a result, based on the findings, males and females in both focus groups seemed to be able to apply these strategies to different types of questions in the focus groups.

Table 5

Occurrence of Systemacity in Both Focus Groups in Response to Different Question Types

	S Perceptions of Biotechnology	S Biotechnology Scenarios	S Perceptions of Critical Thinking	S Overall
Honors	3	13	7	33
Non-honors	0	9	7	16
Males	2	12	8	22
Females	1	10	6	17

Conclusions/Recommendations/Implications

A key implication of this study is the finding that disposition to think critically, as measured by the CCTDI, did increase from the beginning to the end of the course for all students. Interestingly, the increase in score was greater for males than for females, although both groups ended with fairly close scores by the end of the course. Along these same lines, critical thinking disposition scores increased from the beginning to the end of the course for both

non-honors and honors students. Although the average increase was greater for non-honors students, the honors students ended with a slightly higher post test score.

Another key finding involved the way in which honors and non-honors and male and females students applied critical thinking in the focus group sessions. Females were more likely than males to apply critical thinking in scenario based situations while males were more likely to apply critical thinking when answering general content based questions, a finding which may provide evidence to suggest why there may be gender differences with respect to overall critical thinking skills. In addition, in support of Giancarlo and Facione's (2001) findings that students with higher GPAs were more likely to apply Open-mindedness, Analycity, Systemacity, and Maturity, honors students in this study tended to apply these constructs more frequently than did non-honors students. In addition, honors students seemed to be able to apply critical thinking constructs more frequently in discussing their perceptions of critical thinking as it pertained to the class, as well as the way in which they personally perceived themselves as using these skills. In general, honors students seemed to be more cognizant of the way in which critical thinking was used in the curriculum as an instructional technique throughout the semester in the class.

Although these findings are limited to the class in terms of generalizability, the above findings are important, in that they suggest that critical thinking can be an effective instructional technique in a discipline specific context. By the end of the course, student respondents in the study not only increased in overall disposition to think critically, but were able to apply what they learned to the specific content areas, as well as to their evaluations of the course and the use of critical thinking in their own lives. From an agricultural education standpoint, the implication is that teaching for critical thinking can be an effective way to enhance students' thinking abilities in specific content areas. With respect to the agri-sciences, this has great potential, particularly in those disciplines where the subject matter is difficult, fraught with controversy, and/or touches on inherent sociological, environment and political issues that have multiple facets and require complex thought processes. Further, the results indicate that, although high academic achievement status students, such as honors students, might be expected to respond to instruction that would stimulate their critical thinking, non-honors students were able to make gains as well. This would suggest that critical thinking is a skill that can be acquired and developed in all students by agricultural educators who utilize critical thinking instructional techniques where appropriate in their classrooms.

Looking at specific differences among demographic groups in terms of CCTDI change, as well as comparing a treatment class to a control class, are potential directions for future research that could extend the findings of this study. Based on the results, it seems clear that the study of ways to enhance critical thinking among our agriculture students is an area of research that will continue to evolve in the agricultural education discipline as a whole.

References

Armstrong, J. (2000). The value of biotechnology as an incentive for moral evolution [On-line]. Available: http://www.anth.org/ifgene/contents.htm

Ary, D., L. C. Jacobs, et al. (1996). *Introduction to Research in Education.* Orlando, FL, Harcourt Brace & Company.

Carr (1990). *How can we teach critical thinking*? (ERIC Document Reproduction Service No. ED 326 304)

Chaffee, J. (1988). *Thinking critically*. Boston, MA, Houghton Mifflin.

Cheak, M., J. (1999). *The development and field testing of an instrument designed to measure critical thinking in environmental education.* Carbondale, IL, Marie Jaegle Cheak.

Cillizza, J. E. (1970). *The construction and evaluation of a test of critical thinking ability, grades 7-8.* Boston, Boston University School of Education.

Claytor, K. L. (1997). *The development and validation of an adult medical nursing critical thinking instrument (andragogy),* Indiana University.

Dewey, J. (1933). *How we think: A restatement of the relation of reflective thinking to the education process.* Boston, Heath.

Dunne, J. and M. Morgan (1995). "Thinking Critically About Critical Thinking." *Irish Educational Studies*, Educational Studies Association of Ireland **14**.

Ennis, R. H. (1990). "The extent to which critical thinking is subject-specific: Further clarification." *Educational Researcher* **19**: 13-16.

Facione, P. A., N. Facione, et al. (2001). *California Critical Thinking Disposition Inventory: CCTDI Inventory Manual*. Millbrae, CA, California Academic Press.

Facione, P. A., C. F. Facione, et al. (1996). *The California Critical Thinking Disposition Inventory Test Manual*. Millbrae, CA, California Academic Press.

Facione, P. A., C. F. Facione, et al. (1992). *The California Critical Thinking Disposition Inventory: Test Manual*. Millbrae, CA, California Academic Press.

Facione, P. A. (1991). *Using the California Critical Thinking Skills Test in Research, Evaluation, and Assessment*. Millbrae, CA, California Academic Press.

Facione, P. A. (1990). *The California Critical Thinking Skills Test-College Level. Technical Report #2. Factors predictive of CT skills*. Millbrae, CA, California Academic Press.

Facione, P. A. (1990). *Critical thinking: A statement of expert consensus for purposes of educational assessment and instruction*. Millbrae, CA, The California Academic Press**:** 19.

Feely, T. (1975). "Predicting students' use of evidence." *Theory and Research in Social Education* **3**(1): 63-72.

Florida, U. o. (2001). University of Florida Honors Program Admissions [On-line]. Available at http://www.honors.ufl.edu/admissions/admissions.html.

Frisby, C. L. (1992). "Construct validity and psychometric properties of the Cornell Critical Thinking Test (Level Z): A contrasted group analysis." *Psychological* Reports **71**: 291-303.

Giancarlo, C. A. and P. A. Facione (2001). "A Look across Four Years at the Disposition toward Critical Thinking Among Undergraduate Students." *The Journal of General Education* **50**(1): 29-55.

Glaser, E. (1941). *An experiment in the development of critical thinking*. New York, J. J. Little and Ives Company.

Goldberg, M. E., M. Fishbein, et al. (1997). *Social Marketing: Theoretical and Practical Perspectives.* Mahwah, JF, Erlbaum.

Guthrie, J. T., Alao, S., & Rinehart, J. M. (1997). Engagement in reading for young adolescents. *Journal of Adolescent & Adult Literacy, 40*(6), 438–446.

Halliday, J. (2000). "Critical thinking and the academic vocational divide." *The Curriculum Journal* **11**(2): 159-175.

Hallman, W. K. & Metcalf, J. (1995). Public perceptions of agricultural biotechnology: A survey of New Jersey residents. *USDA National Agricultural Library* [On-line]. Available: http://www.nal.usda.gov.bic/Pubpercep/

Halpern, D. F. (1989). *Thought and knowledge: An introduction to critical thinking*. Hillsdale, NJ, Lawrence Earlbaum Associates.

Hedges, L. E. (1991). *Helping students develop thinking skills through the problem-solving approach to teaching*. The Ohio State University, Dr. Lowell Hedges.

Hichey, M. (1990). "Reading and social studies: The critical connection." *Social Education* **54**: 175-179.

Hoban, T. (1998). Trends in consumer attitudes about agricultural biotechnology. *AgBioForum*, **1**(1), 3-7.

Huitt, W. (1998). Critical Thinking. [On-line]. Available: http://chiron.valdosta.edu/whuitt/col/cogsys/critthnk.html

Iverson, M. J. (1998). *Assessing information sources on biotechnology used by teachers of agriculture in the public schools--a tri-state study.* Paper presented at the meeting of the Southern Association of Agricultural Scientists, Agricultural Communications Section, Little Rock, AR. Available On-line: http://agnews.tamu.edu/saas/SAAS2MI.HTM

Jacobs, S. S. (1995). "Technical Characteristics and some correlates of the California Critical Thinking Skills Test forms A and B." *Higher Education Research* **36**: 89-108.

King, P. M., P. K. Wood, et al. (1990). "Critical Thinking among colleges and graduates students." *The Review of Higher Education* **13**(2): 167-186.

Mertes, L. (1991). "Thinking and Writing." *Middle School Journal* **22**: 24-25.

Mines, R. A., P. M. King, et al. (1990). "Stages of intellectual development and associated critical thinking skills in college students." *Journal of College Student Development* **31**: 538-547.

Norris, S. P. and R. H. Ennis (1989). Evaluating critical thinking. *Teaching thinking*. R. J. S. D. N. Perkins. Pacific Grove, CA, Midwest Publications.

Pascarella, E. and P. Terenzini (1991). *How college affects students: Findings and insights from twenty years of research*. San Francisco, CA, Jossey Bass.

Rogers, E. M. (1995). *Diffusion of Innovations*. New York, NY, Free Press.

Rudd, R., M. Baker, et al. (2000). "Undergraduate Agriculture Student Learning Styles and Critical Thinking Abilities: Is there a relationship?" *Journal of Agricultural Education* **41**(3): 2-12.

Salwen, M. B. & Stacks., D. W. (Eds.) (1997). *An Integrated Approach to Communication Theory and Research*. Mahwah, JF, Erlbaum.

Simon, H. A. and C. A. Kaplan (1989). In MI. Posner (Ed), *Foundations of cognitive sciences*. Cambridge, MA, MIT Press**:** 1-47.

Taube, K. (1997). "Critical thinking ability and disposition as factors of performance on a written critical thinking test." *Journal of General Education*.

Walsh, C. M. (1996). *Critical thinking disposition of university students in practice disciplines (nursing, education, and business) and non-practice disciplines (english, history, and psychology): An exploratory study*. College Park, MD, University of Maryland.

Wilson, K. D. (1989). *Predictors of proficiency in critical thinking for college freshmen*. Boseman, MT, Montana State University.

Zinnen, T. (2000). BioIssues. Washington, D.C., GEN National Biotechnology Summit.

A Mixed-Methods Study Of Undergraduate Dispositions Toward Thinking Critically About Biotechnology
A Critique

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"We're working in a brain-based business world. Why do I say brain-based instead of knowledge-based? Because I believe that knowledge is too limited and too static. In this environment, it is not just what you know, but what you can create, implement and communicate. A brain-based business world means that for organizations and individuals, thinking is no longer optional; it is essential. Because in this world, thinking is the new working capital" (Bradford, 2002).

While Dewey may have written "*How We Think*" nearly 100 years ago (1910), we are only beginning to truly comprehend how the mind works and how, as educators, we can use this understanding to prepare a student for a successful future. The researchers for this study are to be commended for advancing our understanding to achieve this end.

A great deal of this paper is dedicated to helping the reader understand the progress that has been made to-date and thus effectively establishes the launching point for this study. The researchers utilized a mixed methodology combining a descriptive survey with focus groups to examine honors and non-honors students in a plant biotechnology course. Both methods were appropriate for the purpose and objectives of this study.

While the design and scope of the study limit any further generalization, two finding cried out to me as items for further consideration.

- *Honors and non-honors students applied different critical thinking constructs*. Why? Does the educational system that nourishes "honors" students facilitate the development of certain constructs or are "honors" student "wired" differently (nature vs. nurture)

- *Females were more likely to apply critically thinking constructs in responses to scenarios, while male were more likely to apply constructs in response to general questions asked*. This finding seemingly adds fuel for the Mars vs. Venus "theory" but is it more than gender differences? Do other factors enhance the likelihood of this difference?

Just something to think about — critically.

Bradford, S. (2002). *Brain power: Maximize your communication and cognition for your business success*. New York: John Wiley & Sons, Inc..