It's in the Genes: Exploring Relationships between Critical Thinking and Problem Solving in Undergraduate Agri-science Students' Solutions to Problems in Mendelean Genetics

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Abstract

This study sought to clarify the relationship between problem solving and critical thinking to guide future teaching and research for agricultural educators using the problem solving approach. Students enrolled in an undergraduate genetics course in a college of agriculture were prompted for use of critical thinking skills in the answer of a problem in the context of biotechnology. Students' critical thinking skills were assessed through content analysis of a think-aloud protocol. Other cognitive factors assessed include problem solving style, problem solving level and critical thinking disposition. A relationship was found between constructs of problem solving style and total critical thinking disposition. Of these cognitive factors, only problem solving level contributed to explaining students' level of correctness in their solution. More research is warranted to bring clarification to these cognitive factors.

Introduction and Theoretical Framework

More than 70 years ago, John Dewey proposed an educational model which gave rise to the philosophical foundation of agricultural education (Talbert, Vaughn, Croom, & Lee, 2006). Dewey (1938) wrote, "The formation of purpose is, then, a rather complex intellectual operation. It involves: 1) observation of surrounding conditions; 2) knowledge of what has happened in similar situations in the past; and 3) judgment, which puts together what is observed and what is recalled to see what they signify" (p.69). Today, researchers and experts in the field of teaching and learning may recognize specific higher level thinking components in Dewey's work; specifically components of problem solving and critical thinking. The problem solving approach has been labeled as "one of the cornerstones of agricultural education instruction" (Cano & Martinez, 1991; p. 24) and is related to critical thinking (Parr & Edwards, 2004), yet research has not confirmed how the two cognitive abilities together contribute to student achievement.

One of the issues in this line of research, especially with respect to research and practice in agricultural education, may be the need to distinguish between dispositional components that

are, essentially, trait-based, and process components which have to do with the level or quality of the method used to solve a problem and/or resolve an issue. This manuscript will therefore examine the distinctions between critical thinking and problem solving as well as how the two are used together in an agri-science course context.

Critical Thinking Skills and Dispositions

Facione (1990) conducted a Delphi study to provide a theoretical framework for identifying critical thinking among college students. Forty critical thinking experts in the disciplines of philosophy, education, social science and physical science contributed to an 87% consensus agreement as to the existence of six critical thinking skills. These six skills include: interpretation–categorizing significant information for better understanding; analysis–identifying relationships between questions, ideas, opinions, judgments and facts; evaluation–determining the credibility of the source as well as logical strength of reasoning; inference–drawing conclusions from facts, opinions, beliefs and concepts; explanation–presenting results of reasoning and justifying procedures used; and self-regulation–assessing reason through self-examination and self-correction (Facione). Facione concluded that these critical thinking skills are tied to higher level thinking, decision making and problem solving, but these relationships were yet to be determined. A review of the literature suggests that the relationship between problem solving and critical thinking still has not been identified.

Many authors have defined critical thinking in their research, each definition adding more understanding to how this cognitive ability may be employed. Pascarella and Terezini (1991) summarized these definitions and concluded that critical thinking is an individual's capability to "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). One can see that this definition resembles the critical thinking skills identified by Facione (1990). Furthermore, a distinction can be made between critical thinking and other higher level thinking skills such as Bloom's (1956) cognitive taxonomy. Whereas critical thinking skills embrace using opinions, beliefs and judgments to facilitate the formation of a rational solution, Bloom's cognitive taxonomy is free of value judgments (Paul, 1985).

Most authors agree on the existence of a critical thinking disposition or tendency. In Facione's (1990) Delphi study, he found that critical thinking is composed of both skills and disposition. Norris (1994) concluded that a critical thinking disposition is necessary for the appropriate use of critical thinking skills. That is, even if students are taught critical thinking skills, they may prefer not to employ those skills. Fortunately, a critical thinking disposition can be improved through proper instruction (Tishman & Andrade, 1996). If critical thinking disposition contributes to the use of critical thinking skills, one would expect a significant relationship. The largest study examining this relationship was Facione and Facione (1997), who examined 7,926 students from 50 different college level programs. Findings included low positive correlations between total skills and total disposition; however not all of the subscales of skill and disposition were significantly correlated, despite the large sample size. Thus, Facione and Facione concluded that these scales could not be correlated.

One of the most often used measures of critical thinking disposition is the 75 item California Critical Thinking Disposition Inventory (CCTDI; Facione, Facione, & Giancarlo, 2001). However, researchers (Rudd, Moore, & Pennfield, 2002) found that not all of the constructs in the CCTDI were supported by evidence provided by a factor analysis. Based on the findings of the factor analysis, the researchers adapted the CCTDI. The resulting instrument was the UF-EMI, which encompassed the constructs: engagement–anticipating opportunities to use reason, cognitive maturity–being aware of own values, beliefs and biases, and innovativeness–seeking to learn with a desire for the truth (Rudd, et al.).

Age and gender are often considered as contributing variables to the explanation of variance in critical thinking skills. For age, many studies indicate that there is no relationship with critical thinking (Cillizza, 1970; Claytor, 1997; Feely, 1975; Facione, 1990; Facione, 1991; Jenkins, 1998; Rodriguez, 2000; Rudd, et al., 2000). However, little research has been conducted outside the college classroom, which tends to exclude youth and the elderly. The variable gender is a bit more contested in the literature, as some authors have found that gender is not related to critical thinking skills (Claytor, 1997; Friedel, Irani, Rudd, Gallo & Eckhardt, in review). On the other hand, some authors have suggested that females tend to have higher levels of critical thinking (Rudd, et al., 2000; Walsh, 1996; Wilson, 1989).

Problem Solving Style and Level

Kirton (2003) asserts that a person's problem solving style can be determined on a continuum of relative adaptiveness and innovativeness. Three constructs make up the total problem score measured by Kirton's Adaption-Innovation Inventory (KAI; Kirton, 1976), including sufficiency of originality, efficiency and rules/group conformity. An individual with an adaptive sufficiency of originality score produces fewer ideas that are considered relevant and useful as opposed to one with an innovative sufficiency of originality score, who produces many ideas of which some may be irrelevant or inappropriate (Kirton). An individual with an adaptive efficiency score solves problems with detailed ideas for a better solution, while one more innovative in efficiency solves problems with broad approaches to make the solution different (Kirton). An individual with an adaptive rules/group conformity score applies rules and structures to solve problems, whereas one more innovative in rules/group/conformity solves problems by overstepping and challenging rules (Kirton). An individual's preferred problem solving style is innate and does not change; however, one may operate in a different problem solving style as the situation requires (Kirton). Solving problems in a style that is not preferred is difficult and stressful for the individual; therefore the individual requires motivation to operate in this dissimilar style. Kirton asserts that problem solving style is independent of problem solving level (which he operationalizes as intelligence) and motivation. That is, all people have the capacity to solve problems, but prefer a distinct style to do so.

Kirton (2003) provides evidence that the general population mean for problem solving style centers on a score of 95 on the KAI. Scores higher than 95 are more innovative and scores lower than 95 are more adaptive with regard to the general population. Women, however, tend to be slightly more adaptive with a mean score of 90. There is no indication that problem solving

style significantly changes with age or with culture (Kirton).

Researchers in the discipline of agricultural education have not examined problem solving style as a contributor to critical thinking with exception of the study conducted by Torres and Cano, (1995) who used the Group Embedded Figures Test (GEFT; Witkin, Oltman, Raskin & Karp, 1971) to measure learning style and the Developing Cognitive Abilities Test (DCAT; Beggs & Mouw, 1989) to measure critical thinking skills. The GEFT determines if one is field dependent or field independent in learning a concept, not problem solving style. However, Witkin (1973) found the GEFT may suggest a preference for structure. Field dependent learners tend to prefer more structure in solving problems while field independent learners prefer less structure while solving problems. This corresponds to Kirton's (2003) view of adaptive individuals, who favor structure, and innovative individuals, who prefer less structure. In the Torres and Cano (1995) study, students' GEFT score contributed to an additional 9% of the variance in DCAT scores, indicating that students having a field-independent learning style may have higher critical thinking scores. Torres and Cano gave little explanation as to why this relationship may have existed; but the finding poses the question, is problem solving style related to critical thinking skills?

The Problem Solving Process

A problem can be defined as a desire or felt need for a solution, but not immediately knowing the mental operations to arrive at the solution (Soden, 1994). Although not all the mental operations may be known, the process is agreed upon by most psychologists. In the literature, the problem solving process generally consists of four stages: problem identification, solution generation, solution evaluation, and solution execution (Pretz, Naples, & Sternberg, 2003). It is important to note that the problem solving process corresponds with problem solving learning, just as the process used to learn a concept corresponds to conceptual learning (Gange, 1965). Gange wrote that learning is hierarchical, with problem solving learning ranking as the highest level of learning to which the other seven types of learning contribute. Gange's work was corroborated by Anderson, Krathwohl & Bloom (2001) who concluded that the act of creating was more difficult than Bloom's (1956) other cognitive skill levels. Note that the act of creating uses a similar cognitive process as problem solving (Kirton, 1999; Wallas, 1926).

The problem solving approach has been researched and supported as a mainstay for agricultural education (Boone, 1990; Flowers & Osborne, 1988; Parr & Edwards, 2004; Stewart, 1950). Yet, research in agricultural education has focused only on how the problem solving approach affects student achievement and learning of content. Other researchers in agricultural education have examined uses of higher level thinking (Whittington, 1998) and critical thinking (Cano & Martinez, 1991; Rollins, 1990; Rudd, Baker, & Hoover, 2000; Torres & Cano, 1995), but have not examined how these thinking skills relate to problem solving. If agricultural education continues to use the problem solving approach to teach students and acknowledges the existence of other higher level thinking skills, research is needed to determine the relationship between these two aspects of cognition.

Critical Thinking and Problem Solving

Drawing from the work of Swartz and Perkins (1990), Hedges (1991) adapted a model that incorporated critical thinking skills into the problem solving teaching approach. Hedges claimed that in order to teach using the problem solving approach, the problem solving process must serve as the foundation of the lesson. Critical thinking skills were then taught repeatedly within each step of the problem solving process. However, neither Swartz and Perkins or Hedges considered the influence of students' individual differences in using critical thinking skills in the problem solving process. Among these individual differences include varying levels of a critical thinking disposition which is necessary in employing critical thinking skills (Facione, 1998). Also, Kirton (2003) provides evidence that an individual's problem solving style indicates a preferred method to solving a problem. That is, an individual with a different problem solving style has a different approach to each of the four steps in the problem solving process. Although little research has been conducted as to how Kirton's measure of problem solving style relates to critical thinking skills, Kirton suggests that more innovative individuals tend to use deductive thinking and more adaptive individuals tend to use inductive thinking (Kirton). Problem solving style is independent of problem solving level or intelligence (Kirton). However, the relationship between problem solving level and critical thinking disposition may be related. Tishman and Andrade (1996) discussed that since a critical thinking disposition can be learned, it must have an association with intelligence. However, previous research has found that correlations between intelligence and critical thinking dispositions are low (Giancarlo & Facione, 2001; Ricketts & Rudd, 2005).The relationships between problem solving style and critical thinking disposition have not yet been fully explored. Nevertheless, it is evident that problem solving style, problem solving level and critical thinking disposition each contribute to the employment of critical thinking skills during the problem solving process.

Consideration of these individual differences is essential in understanding how these cognitive factors are related and provides a foundation for future research. Figure 1 shows a diagram of how these cognitive factors may be employed during the problem solving process.

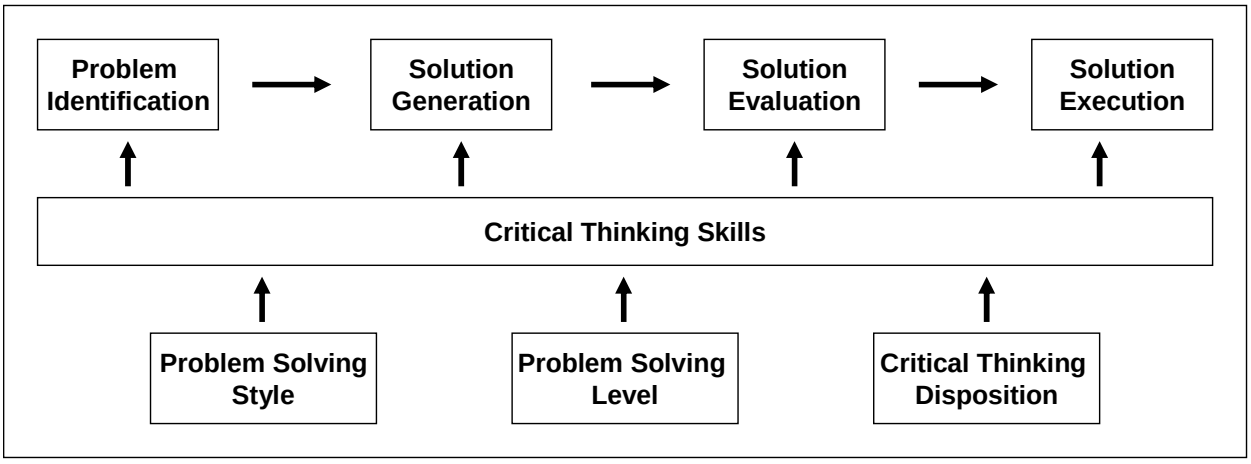

Figure 1. A Conceptual Model of Cognitive Factors Utilized in the Problem Solving Process. Modified from Swartz and Perkins (1990) and Hedges (1991).

Although this conceptual model provides understanding to the relationships between components of critical thinking and problem solving, it has yet to be empirically tested. How does critical thinking facilitate the problem solving process?

Purpose and Objectives

The purpose of this study was to explore how critical thinking skills and dispositions are related to problem solving styles and levels among undergraduate students studying genetics in a college of agriculture. The specific objectives of the study were to:

1. Determine selected demographic information of undergraduate students enrolled in AGR 3303C–Genetics.
2. Determine undergraduate students' critical thinking skill level, critical thinking disposition, problem solving level, problem solving style and correctness of solution.
3. Determine relationships between critical thinking skill, critical thinking disposition, problem solving style, problem solving level, correctness of solution and selected demographics.
4. Explain students' correctness of solution based on critical thinking skill, critical thinking disposition, problem solving level, problem solving style and selected demographics.

Procedures

To conduct the study, an undergraduate introductory class in genetics was utilized. Genetics was determined by the researchers to be a good study environment, due to the focus on inquiry based and problem solving approaches. According to the course instructor, Mendelean genetics includes both fact based knowledge acquisition and employment of this knowledge in solving higher level problems requiring critical thinking skills of analysis, inference, and evaluation (Gallo, personal communication, 2006).

To better describe the relationships between critical thinking and problem solving, qualitative and quantitative data was collected. The population of study comprised 152 students enrolled in a science based course in the college of agriculture and life sciences at a large Southeastern university, of which 108 agreed to participate.

Study participants met individually with a research administrator outside of class in an interview setting. Participants were asked to complete two assessments: the EMI to determine their critical thinking disposition, and the KAI to determine their problem solving style. Once the inventories were completed, the researcher presented the student with one of four predetermined problems that were written in the context of Mendelean genetics and prompted students to use critical thinking skills. The problems were developed with the help of the course instructor and were based on material covered in class. Participants were asked to read the question out loud and discuss an answer to the problem. Responses were audibly recorded on a computer in order to observe the critical thinking skills being utilized. Demographic data and self-reported GPA was collected for descriptive purposes. The course instructor provided final grades for students and evaluated students' critical thinking solutions for correctness.

Instrumentation

To identify critical thinking skills, a rubric was developed by an expert panel of researchers and practitioners to determine prominent subset skills for each of the six critical thinking skills identified by Facione (1990). Only three of the six critical thinking skills were coded, as Facione determined that measuring analysis, evaluation and inference provided the only accurate measure of overall critical thinking abilities from a statistical standpoint. This rubric was used to score students' critical thinking skills as they audibly answered one of four questions developed by the researchers and course instructor.

Think-aloud protocols were used to better determine critical thinking skills that occur during the problem solving process (van Someren, Barnard, & Sandber, 1994). The process includes a practice session in which the student is prompted to answer a question by thinking out loud everything that comes to mind and used to relieve nervousness (van Someren, et al.). After the practice session, the student was asked if he or she would like to continue with the experiment. Students who continued were given a question which prompted for the critical thinking skills analysis, evaluation and inference. Students were not given a time limit and were only interrupted when they had quit talking for a short period of time, at which point they were prompted to keep talking (van Someren, et al.). Evidence has shown that verbally expressing thoughts does not alter those thoughts, but may slow down the performance of thinking (Ruiz-Primo, Shavelson, Li, & Schultz (2001). Think-aloud protocols used in this manner have been determined valid theoretically (Ericsson & Simon, 1993) and empirically with college students (Ransdell, 1995) for examining cognitive processes.

All critical thinking answers were audibly recorded on a computer. Content analysis of the recordings was conducted using the aforementioned rubric in identifying the critical thinking skills articulated by the students. Content analysis has been defined as "the systematic assignment of communication content to categories according to rules, and the analysis of relationships involving those categories using statistical methods" (Riffe, Lacy, & Fico, 1998, p. 2). This methodology has been found reliable based on the fact that coders utilize identical classification guidelines when assigning numerical values to qualitative content (Riffe, et al.).

To determine critical thinking disposition, the University of Florida-Engagement, Maturity, and Innovativeness (UF-EMI) assessment was used. The 26-item instrument measures three constructs of critical thinking: engagement, maturity, and innovativeness, through five-point Likert scale questions. The scores from the instrument can range from 26 (low disposition) to 130 (high disposition). The UF-EMI was developed by researchers at the University of Florida (Rudd, Moore, & Pennfield, 2002) from a factor analysis of the CCTDI. The UF-EMI was also used to collect selected demographic information.

The Kirton Adaption-Innovation (KAI) inventory was utilized to determine participants' problem solving style. The KAI inventory requires respondents to indicate their degree of ease or difficulty encountered while sustaining their adaptive or innovative behaviors over periods of time on a series of 32 five-point scaled items (Foxall & Bhate, 1993). Responses are computed into overall scores ranging from 32 to 160 (Foxall & Haskins, 1986). Individual scores are

composed of three independent sub-scales which measure originality (13 items), efficiency (seven items), and rule-conformity (12 items) (Goldsmith, 1984). Respondents scoring below the 96 mid-point are considered "adaptors," while those above 96 are "innovators" (Foxall & Haskins, 1986). Kirton (1999) provides evidence of established reliability and validity from a compilation of his research as well as reported research from many different authors.

Problem solving level was operationalized by the final course grade students received after completion of AGR 3303C. The course commonly used problem sets incorporated in instruction, and exams were comprised of problem solving scenarios requiring students to provide an answer, similar to the protocol performed in the data collection portion of the study.

Students' recorded solutions were evaluated on a 5-point scale by the AGR 3303C course instructor for correctness. This scale was coded one for exhibiting low level of correctness and five for exhibiting high level of correctness and operationalized the students' executed solution.

Data Analysis

Descriptive statistics were used to analyze demographic information, critical thinking skill, critical thinking disposition, problem solving style, problem solving level, and correctness of solution. Pearson's correlation coefficient was utilized to determine relationships between critical thinking skill, critical thinking disposition, problem solving style, problem solving level correctness of solution and selected demographic information. Finally, backward stepwise multiple regression was used to determine students' correctness of solution as a factor of critical thinking skill, critical thinking disposition, problem solving style, problem solving level and selected demographic information.

To analyze the qualitative data for determining critical thinking skills, 108 audio recordings were randomly divided among two coders. Coder training was held with the lead researcher. Coders were instructed to listen to each recording three times to listen for coding categories in critical thinking analysis, evaluation, and inference. A total of 19 categories (split into the three sub categories of analysis, evaluation, and inference) were coded for, and coders were to assign a value of 1 (no demonstration of the critical thinking sub-scale) to 3 (mastery of the critical thinking skill) in each category. Answers to each problem developed by the course instructor were presented to the coders to help give them an idea of the content discussed; however at this point correct answers were not coded for, just critical thinking skills. Coders initially coded 11 recordings (10% of the sample) to reach a Holsti's intercoder reliability of .88 (North, Holsti, Zaninovich & Zinnes, 1963). Coders then completed coding the recordings over a three week time span. Data was entered into SPSS for further analysis.

Findings

The UF-EMI had an acceptable post-hoc reliability coefficient for total critical thinking disposition score (α=.84) and the engagement construct (α=.84). However, reliability coefficients were less than desirable for the disposition constructs cognitive maturity (α=.39) and innovativeness (α=.63). The researchers acknowledge that the UF-EMI is still under

development, but note that the instrument had acceptable reliability in previous studies (Friedel, et al., in review). Because of lower reliability, only the total critical thinking score was used in data analysis.

The first objective of this study was to determine selected demographic information of undergraduate students enrolled in AGR 3303C–Genetics. In this course, 108 students volunteered to participate. For the respondents, one student classified himself as a graduate student and he was removed from the data leaving 107 (70.4%) respondents. Of the remaining participants 78 were female (72.9%) and 29 were male (27.1%). The mode age for this group was 21 years with everyone below the age of 25 years, except for one 36 year-old student. Most of the students were seniors (*n*=65, 60.7%) while 36 (33.6%) classified themselves as juniors and 6 (5.6%) were sophomores.

There were17 academic majors and one undecided student in the class. The most common academic majors were animal science (*n*=32, 29.9%), human nutrition (*n*=30, 28.0%) and nutrition (*n*=13, 12.1%). None of the remaining 14 academic majors made up more than 6.0% of the students. There were 25 (23.4%) honors students and the overall mean self-reported cumulative GPA was 3.41. The descriptive data for the participants indicated that for the most part, these were traditional students in terms of age and college major; animal sciences and food science/human nutrition are the largest majors in the college of agriculture at this institution.

The second objective addressed by this study was to determine undergraduate students' critical thinking skill level, critical thinking disposition, problem solving style, and problem solving level. For critical thinking skill level, as operationalized using the critical thinking rubric, the mean score was 32.94 (*SD*=6.25). The student who scored the lowest for critical thinking skills scored 18 points on the rubric while the student with the highest level of critical thinking skill scored 48 points on the rubric. The total range of the critical thinking skills rubric was 18 to 54. Note that one student did not answer the questions to assess critical thinking skills.

Table 1
Student Mean Scores of Critical Thinking Skills (n=106)

Construct	Mean	SD	Min	Max
Total critical skills	32.95	6.25	18	48
Analysis	13.04	2.41	6	18
Evaluation	9.68	2.55	6	16
Inference	10.24	2.52	6	16

Note. Critical thinking skills measured by a rubric through content analysis with 18 items. Theoretical range: Total skills (18-54), all three constructs (6-18).

The critical thinking disposition mean score for participants was 102.64 (*SD*=14.47). The student who had the lowest critical thinking disposition scored 71 points on the UF-EMI while the student with the highest critical thinking disposition scored 126 points. The total range of the UF-EMI was 26 to 130. See Table 2.

Table 2
Student Mean Scores of Critical Thinking Disposition (n=107)

Construct	Mean	SD	Min	Max
Total critical thinking disposition	102.64	9.37	71	126
Engagement	42.41	5.56	22	54
Cognitive maturity	30.12	3.16	21	38
Innovativeness	30.10	2.80	21	35

Note. Critical thinking disposition measured by the EMI with 26 items. Theoretical range: Total disposition (26-130), Engagement (11-55), Cognitive Maturity (8-40) and Innovativeness (7-35).

Concerning the problem solving style of responding students in AGR 3303C, the mean score was 93.95 (*SD*=14.09) which was 1.05 points more adaptive than the general population mean reported by Kirton (2003). Of the respondents, the most adaptive student had a total problem solving score of 61 points while the most innovative student had a problem solving score of 138 points. See Table 3.

Table 3
Student Mean Scores of Cognitive Style Constructs (n=81)

Construct	Mean	SD	Min	Max
Total cognitive style	93.95	14.09	61	138
Sufficiency of originality	41.91	7.50	27	58
Efficiency	16.71	4.31	9	28
Rule/Group conformity	35.32	7.35	17	54

Note. Problem solving style measured by the KAI with 32 items. Theoretical range: Total (32-160), Sufficiency of Originality (13-65), Efficiency (7-35) and Rule/Group Conformity (12-60). Coded: lower score equals more adaptive, higher score equals more innovative.

This study operationalized problem solving level as students' final percentage grade for AGR 3303C. For the 107 participants, the final grade mean was 80.98 (*SD*=12.15). Among these participants, the lowest final grade was a 38% and the highest final grade was 97%.

Students' level of correctness in their solution to the genetics problem posed by the researchers had a mean score of 2.51 (*SD*=1.14). On a scale from one to five with one indicating little correctness and five indicating high correctness, 20.8% of the participants scored one, 33.0% scored two, 26.4% scored three, 14.2% scored four and 5.7% scored five.

For objective three, Pearson's correlation coefficient was used to determine relationships between critical thinking skill, critical thinking disposition, problem solving style, problem solving level and selected demographics.

Based on this analysis, students' total critical thinking skill scores had no significant correlations with problem solving style (r=.03, p>.05), problem solving level (r=.11, p>.05) or critical thinking disposition (r=07, p>.05); all indicating no relationship. There were, however, high correlations between total critical thinking skill and critical thinking skill constructs analysis (r=.82, p<.05), evaluation (r=.84, p<.05) and inference (r=.87, p<.05). These values indicate that

critical thinking constructs were closely related to the measure of total critical thinking skills.

Total critical thinking disposition as determined by the EMI was not significantly correlated with the total measure of problem solving style (r=.19, p>.05), but was moderately correlated with the problem solving style construct sufficiency of originality (r=.47, p<.05) and negatively correlated with the problem solving style efficiency construct (r=-.35, p<.05). The data suggests from these correlations that a higher critical thinking disposition is associated with an innovative sufficiency of originality score and an adaptive efficiency score. That is, a higher level of critical thinking disposition is coupled with generating many ideas, but utilizing detailed methods and narrow focus. Critical thinking disposition was not significantly correlated with problem solving level (r=.19, p>.05) suggesting no association. Total critical thinking disposition was highly correlated with internal disposition constructs engagement (r=.91, p<.05), cognitive maturity (r=.65, p<.05) and innovativeness (r=.83, p<.05) indicating a close relationship between the constructs of critical thinking disposition and the total measure of critical thinking disposition.

Students' problem solving style was measured utilizing the KAI. There was no significant correlation between total problem solving style and problem solving level (r=-.08, p>.05) indicating no relationship. Total problem solving style was highly correlated with its internal constructs sufficiency of originality (r=.80, p<.05) and rule/group conformity (r=.88, p<.05) and moderately correlated with the efficiency construct (r=.38, p<.05). These correlations indicated a close association between total problem solving style and the constructs making up problem solving style.

Students' problem solving level was negatively correlated with age (r=-.35, p<.05), indicating an association between higher problem solving ability and younger students. Interestingly, problem solving level was negatively correlated with being classified as an honors student (r=.-33, p<.05). This finding suggests that honors students were not associated with higher problem solving ability in this class. As expected, problem solving level was highly correlated with self-reported cumulative GPA (r=.70, p<.05) suggesting a close relationship. Students' self-reported cumulative GPA was moderately correlated with total critical thinking disposition (r=.29, p<.05). This data suggests that in this class, higher self-reported GPA was associated with higher levels of critical thinking disposition. No other demographic variables, including gender, were significantly correlated with the cognitive factors measured in this study. Finally, only problem solving level correlated with correctness of the solution to the problem (r=.33, p<.05) which suggests that higher problem solving level was coupled with a higher degree of correctness to solutions to these problems.

For objective four, backward stepwise multiple regression was employed to explain students' correct response based on critical thinking skill, critical thinking disposition, problem solving level, problem solving style and selected demographics. Only problem solving level significantly contributed to explaining these students' ability to arrive at the correct solution. To interpret, students with a problem solving level of 80 points have an average correctness of solution score of 2.59. This compares to students with a problem solving level of 90 points having an average correctness of solution score of 2.99. This data suggests that participants with

a higher problem solving level have higher levels of correctness in their solutions to the posed questions. The data also suggests that problem solving style, critical thinking disposition and critical thinking skills did not contribute to correctness of solution for these students. See Table 4.

Table 4
Backward Stepwise Multiple Regression Explaining Correct Solution (n=80)

Construct	B	SE	Beta	t.	Sign.	Model F	Sign.
(Constant)	-0.61	1.05		-0.58	.56	9.48	.00
Problem Solving Level	0.04	0.01	.33	3.08	.00		

Note. Adjusted R^2=.10

Conclusions

The results of this study provide support for the association between constructs of critical thinking disposition and problem solving style, and for the relationship between critical thinking disposition and self reported GPA, and problem solving level and GPA.

Overall, students in this study were of traditional student age, mostly upperclassmen, majoring in animal sciences and nutrition/nutritional science majors. Their critical thinking skill score, as measured via the rubric employed in this study, ranged from a score of 19 to 54 points on the scenario based problems students were assigned to solve. Their critical thinking dispositional score, as measured via the UF-EMI, ranged from a low of 26 to a high of 130. With respect to problem solving style, these students were slightly more adaptive than the reported population mean for the KAI. In terms of performance, operationalized for this study as problem solving level, the final grade mean was 80.98 (*SD*=12.15). Among these participants, the student with the lowest final grade was a 38% and the highest final grade was a 97%. On a scale of one to five, students' correctness of answer mean was 2.51 (*SD*=1.14).

In this study, total critical thinking disposition was not significantly correlated with the total measure of problem solving style, but was moderately correlated with the problem solving style construct sufficiency of originality and negatively correlated with the problem solving style efficiency construct, suggesting that a higher critical thinking disposition is associated with an innovative sufficiency of originality score and an adaptive efficiency score. Problem solving level was negatively correlated with age suggesting an association between higher problem solving ability and younger students. Problem solving level was negatively associated with honors students in this class, but was highly correlated with self-reported cumulative GPA. No significant relationship was found between critical thinking skills and critical thinking disposition in these students. A low but significant relationship was found between critical thinking disposition and self-reported cumulative GPA. No other significant relationships existed between demographic variables and cognitive factors measured in this study.

In this study, only problem solving level contributed to explaining the level of correctness in solutions provided by these students. This finding suggests problem solving style is unrelated

to one's ability to solve problems (Kirton, 2003). The data also suggests that critical thinking skills, a higher level cognition that embraces value judgments (Paul, 1985), was not related to correctness of solution.

Recommendations and Implications

- Results should not be applied beyond this population due to the use of an intact group. There may also be limitations due to instrumentation used in this study, specifically critical thinking disposition and the measure of problem solving level.

- More research is needed to identify the relationship between problem solving style and critical thinking disposition. If a relationship is confirmed, education practitioners should be taught how to operate in a different problem solving style to better facilitate use of critical thinking skills.

- This study found positive but low correlations between critical thinking skills and critical thinking disposition; albeit not significant, this is congruent with research by Facione and Facione (1997). Practitioners should be made aware that critical thinking disposition is a separate component and necessary for using critical thinking skills (Facione 1990).

- Students' level of correctness of solution was only significantly explained by problem solving level. More research is warranted to examine how critical thinking relates to conceptual learning (Gange, 1965).

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