

IT'S IN THE GENES: EXPLORING RELATIONSHIPS BETWEEN CRITICAL THINKING AND PROBLEM SOLVING IN UNDERGRADUATE AGRISCIENCE STUDENTS' SOLUTIONS TO PROBLEMS IN MENDELIAN GENETICS

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Abstract

This study was conducted to examine the statistical 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 the College of Agricultural and Life Sciences at the University of Florida were prompted to use their critical-thinking skills while answering 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 included problem-solving style, problem-solving level, and critical-thinking disposition. A path analysis was used to examine how these trait-based variables and use of critical-thinking skills contribute to solving a problem. Of these cognitive factors, only problem-solving level, critical-thinking disposition, and use of critical-thinking skills were included in the revised model. The authors argue that although correlations were significant, they were low and indicated that critical thinking and problem-solving may be more independent than previously thought. Limitations of this study require more research to better understand how these cognitive factors are employed by the learner to solve problems.

Introduction and Theoretical Framework

More than 70 years ago, John Dewey proposed an educational model that 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 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. Furthermore, little examination has been given to both 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. The authors will therefore examine the distinctions between critical thinking and problem solving as well as how the two are used together in an agriscience course context.

Critical-Thinking Skill Level and Dispositions

Facione (1990) conducted a Delphi study to provide a theoretical framework for identifying critical thinking among college students. The resulting six skills included 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 suggested more research was needed to empirically determine these relationships.

Many authors have defined critical thinking in their research, with 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 was composed of both skill and disposition. Norris (1994) concluded that a critical-thinking disposition was 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, instructional methods that promote critical thinking can improve students' disposition (Tishman & Andrade, 1996).

Age and gender are often considered as contributing variables to the explanation of variance in critical-thinking skill level. For the variable age, some studies have provided evidence that there was no relationship with aspects of critical thinking (Claytor, 1997; Facione, 1990; Rudd, Baker & Hoover, 2000). However, little research has been conducted outside the college classroom, which tends to exclude youth and the elderly. The variable "gender" was a bit more contested in the literature, as some authors have found that gender was not related to critical-thinking skill level (Claytor; Friedel, Irani, Rudd, Gallo & Eckhardt, in press). 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. An individual identified as more adaptive may precisely define the problem but will tend to have solutions that are narrowly focused on improving efficiency and that are tightly held within the given rules of the situation (Kirton). An individual identified as more innovative may loosely define the problem but will tend to have many different solutions that cut across paradigms and may challenge or overstep the rules found within the context of the situation (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). Kirton asserts that problem-solving style is independent of problem-solving level (which he associated with intelligence) and motivation. That is, all people have the capacity to solve problems, but prefer a distinct style to do so.

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 skill level. Although the GEFT does not determine problem-solving style, Witkin (1973) found the GEFT may suggest a preference for structure in the learning process. Field dependent learners tend to prefer more structure in solving problems; field independent learners prefer less structure. This relationship corresponds to Kirton's (2003) adaptive individuals, who favor structure, and innovative individuals, who prefer less structure while solving problems. In the Torres and Cano study, students' GEFT score contributed to an additional 9% of the variance in DCAT scores, indicating that students having a field-independent learning style, preferring less structure, may have higher critical-thinking scores. Torres and Cano gave little explanation as to their findings; but this poses the question, does problem-solving style have a relationship with critical-thinking skill level?

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 as consisting of four stages: problem identification, solution generation, solution evaluation, and solution execution

(Pretz, Naples, & Sternberg, 2003). Gagne (1965) wrote that learning processes are hierarchical with learning from problem solving ranking highest among the other seven types of learning: principle, conceptual, discrimination, verbal, chaining, stimulus-response, and signal.

Critical Thinking and Problem Solving

The problem-solving approach has been researched and supported as a mainstay for agricultural education (Boone, 1990; 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 et al., 2000; Torres & Cano, 1995) but have not examined how these thinking skills relate to 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 instructional 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 nor Hedges considered the influence of students' individual differences in using critical-thinking skills in the problem-solving process. The literature provided evidence that problem-solving style, problem-solving level, and critical-thinking disposition each contributed to the employment of critical-thinking skill level 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.

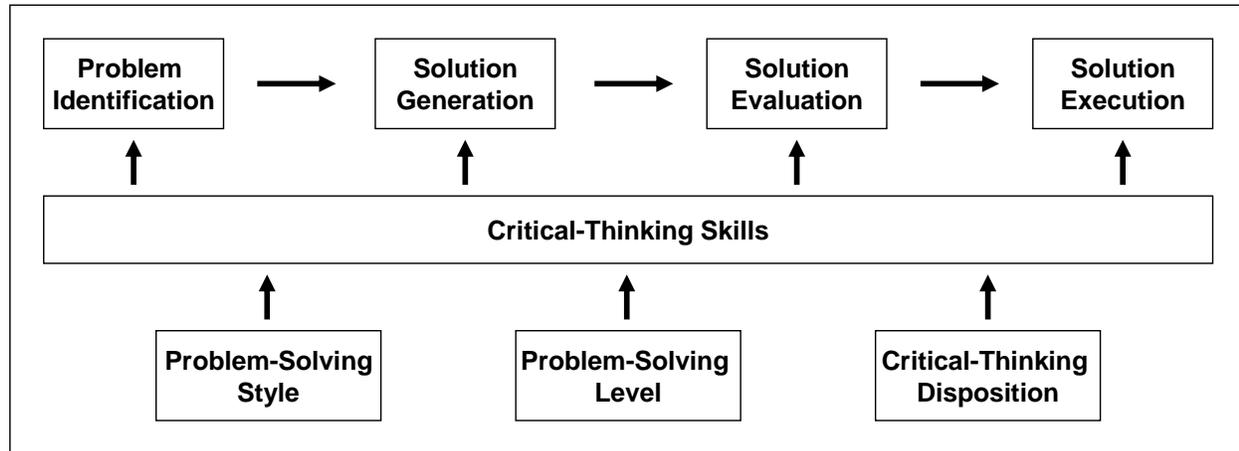


Figure 1. A conceptual model of cognitive factors utilized in the problem-solving process.

Note. From *Helping Students Develop Thinking Skills Through the Problem-Solving Approach to Teaching* (p. 2), by L. E. Hedges, Unpublished manuscript, The Ohio State University. Adapted with permission.

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? Note that critical-thinking skills may be employed within each stage of the problem-solving process, however this study only examined relationships with the final solution; the outcome of this process.

Purpose and Objectives

The purpose of this study was to explore how individual characteristics associated with cognitive function were related to critical-thinking skills and the problem-solving process among undergraduate students studying genetics in a college of agriculture. The objectives of the study were to (a) determine selected demographic information of undergraduate students enrolled in AGR 3303C–Genetics; (b) determine undergraduate students' critical-thinking skill level, critical-thinking disposition, problem-solving level, problem-solving style, and correctness of solution; and (c) determine relationships between critical-thinking skill level, critical-thinking disposition, problem-solving level, problem-solving style, correctness of solution, and selected demographics.

Procedures

To conduct this study, an undergraduate introductory class in genetics was chosen by the researchers to be an appropriate study environment because of the focus on inquiry based and problem-solving teaching approaches. According to the course instructor, Mendelian genetics includes both fact-based knowledge acquisition and the application of this knowledge to solving problems requiring higher levels of the critical-thinking skills analysis, inference, and evaluation (M. Gallo, personal communication, August 18, 2006). This intact group comprised 152 students enrolled in a science-based course in the *College of Agricultural and Life Sciences at the University of Florida*. From this group, 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 University of Florida Engagement, Maturity, and Innovativeness test (UF-EMI; Moore, Rudd & Pennfield, 2002) to determine their critical-thinking disposition, and Kirton's Adaption-Innovation Inventory (KAI; Kirton, 1976) to determine their problem-solving style.

Once the inventories were completed, each student was presented with one of four predetermined problems that were written in the context of Mendelian genetics with the

intention to prompt 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. Each student's solution to the randomly assigned problem was audibly recorded on a computer in order to observe the critical-thinking skill level being utilized. 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. Demographic data and self-reported GPA was collected for descriptive purposes. The course instructor provided final grades for students and evaluated students' answers for correctness of the solution.

Instrumentation

To identify students' critical-thinking skill level, a rubric was developed by an expert panel of researchers and practitioners to determine prominent subset skills for the aforementioned critical-thinking skills: analysis, evaluation, and inference. Measurement of these three skills has been determined to best represent total critical-thinking skills defined by Facione (1990). Researchers applied the developed rubric through content analysis methodology by analyzing students' audible recordings and assigning a numerical score for the three critical-thinking skills assessed in this study. 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 UF-EMI assessment was used. The 26-item instrument measures three constructs of critical thinking: engagement—anticipating situations to use

critical-thinking skills, maturity—being aware of own values and biases, and innovativeness—being intellectually curious to find the truth (Irani et al., 2007). The constructs summate a total score ranging from 26 indicating a low disposition to 130 indicating a high disposition (Irani et al.). Kirton (2003) stated that problem-solving level, or ability to solve problems, included factors of knowledge, experience and skill. Problem-solving level was operationalized in this study by the final course grade students received after completion of AGR 3303C. This 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, and therefore determined to be a valid measure of problem-solving style. The KAI was utilized to determine participants' problem-solving style. Constructs of problem-solving style as measured by the KAI include: sufficiency of originality—a preference for forming solutions, efficiency—a preference to strategy in solving problems, and rule/group conformity—a preference for structure during problem solving (Kirton). Responses on the 32-item instrument are computed into overall scores ranging from 32 to 160 with a general population mean of 95 (Kirton). (Should this be 96? $160+32/2=96$) Respondents scoring below 95 points are considered more adaptive and those scoring above 95 points are more innovative when compared to the general population (Kirton). Kirton provided evidence of established reliability and validity from a compilation of his research as well as reported research from many different authors. Finally, students' executed or final solutions were operationalized by the audibly recorded answers to the Mendelian problem and were evaluated on a 5-point scale by the AGR 3303C course instructor for correctness. This scale was coded 1 for exhibiting low level of correctness and 5 for exhibiting high level of correctness.

Data Analysis

Descriptive statistics were used to analyze demographic information, critical-

thinking skill level, 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 level, critical-thinking disposition, problem-solving style, problem-solving level correctness of solution, and selected demographic information. Finally, a path analysis was conducted to identify causal relationships among the variables.

To analyze the qualitative data for determining critical-thinking skill level, 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 and assign a score in each of the 18 coding categories that identified the three critical-thinking skills analysis, evaluation, and inference. A score of 1 indicated no demonstration of critical thinking, a score of 2 indicated little demonstration of critical thinking and a score of 3 indicated mastery of the critical-thinking skill. 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 3-week time span.

Finding

The UF-EMI had acceptable post-hoc reliability coefficients for total critical-thinking disposition score ($\alpha = .84$) and the engagement construct ($\alpha = .84$). However, reliability coefficients were less than desirable for the disposition constructs cognitive maturity ($\alpha = .39$) and innovativeness ($\alpha = .63$). Because of lower construct reliability, only total critical-thinking disposition 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 was classified as a graduate student and was removed from the data, leaving 107 respondents. Of the remaining participants, 78 were female

(72.9%). 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 students were seniors ($n = 65, 60.7\%$), 36 (33.6%) classified themselves as juniors, and 6 (5.6%) were sophomores.

There were 17 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 were the largest majors in the college of agriculture.

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

The total critical-thinking disposition mean score for participants was 102.64 ($SD = 9.37$). The student with the lowest critical-thinking disposition scored 71 points on the UF-EMI; the student with the highest critical-thinking disposition scored 126 points (Table 2).

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%.

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, whereas the most innovative student had a problem-solving score of 138 points (Table 3).

Table 1
Student Mean Scores of Critical-thinking Skill Level (n = 106)

Construct	<i>M</i>	<i>SD</i>	<i>Min.</i>	<i>Max.</i>
Total critical skill level	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 skill level measured by a rubric through content analysis with 18 items. Theoretical range: Total skill level (18 to 54), all three constructs (6 to 18).

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

Construct	<i>M</i>	<i>SD</i>	<i>Min.</i>	<i>Max.</i>
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 to 130), Engagement (11 to 55), Cognitive Maturity (8 to 40), and Innovativeness (7 to 35).

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

Construct	<i>M</i>	<i>SD</i>	<i>Min.</i>	<i>Max.</i>
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 to 65), Efficiency (7 to 35), and Rule/Group Conformity (12 to 60). Coded: lower score equals more adaptive, higher score equals more innovative.

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 1 to 5 with 1 indicating little correctness and 5 indicating high correctness, 20.8% of the participants scored 1, 33.0% scored 2, 26.4% scored 3, 14.2% scored 4, and 5.7% scored 5.

For objective 3, Pearson's correlation coefficient was used to determine relationships between critical-thinking skill level, critical-thinking disposition, problem-solving level, problem-solving style, and selected demographics. Based on this analysis, students' total critical-thinking skill level 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 relationships.

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 ($r = -.35, p < .05$). These findings indicated that a higher critical-thinking disposition was associated with an innovative sufficiency of originality score and an adaptive efficiency score. That is, a higher level of critical-thinking disposition was coupled with generating many ideas but utilizing a strategy of thoroughness and attention to detail. Critical-thinking disposition was not significantly correlated with problem-solving level ($r = .19, p > .05$), suggesting no relationship.

There was no significant correlation between total problem-solving level and problem-solving style ($r = -.08, p > .05$) as measured by the KAI, indicating no relationship. Students' problem-solving level was negatively correlated with age ($r = -.35, p < .05$), indicating an association between higher problem-solving ability and younger students. Also, 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 ($r = .29, p < .05$). To interpret this finding, higher self-reported GPA was associated with higher levels of critical-thinking disposition in this class. No other demographic variables, including gender, were significantly correlated with the cognitive factors measured in this study. 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.

Finally, a path analysis was conducted to further examine the correlations and identify causal effects of trait-based variables and critical-thinking skill level on forming a correct solution by the students enrolled in this genetics class. Note that this study was conducted only to examine the executed solution of the problem-solving process and not problem identification, solution generation and solution evaluation; although it is assumed that these prerequisite stages were used to complete the problem-solving process. The empirical data obtained in this study did not support the initial conceptual model (Figure 1). Two of the reproduced path correlations exceeded a .05 difference from original empirical correlations, indicating a lack of fit (Mertler & Vannatta, 2002). To better fit the model, all paths associated with problem-solving style were removed as they were not statistically significant. Then alternative paths were explored; however, no other additional paths significantly contributed to the model. The revised model was found to be significant and included problem-solving level, critical-thinking disposition and use of critical-thinking skills to form a correct solution (Table 4, Figure 2).

Table 4
Causal Effects of Revised Model Shown in Figure 2 (n = 106)

Dependent variable	Independent variable	Causal Effects		
		Direct	Indirect	Total
Critical-thinking skill (R ² = .03)	Problem-solving level	.11	-	.11 ⁺
	Critical-thinking disposition	.14	-	.14 ⁺
Correct solution (R ² = .15)	Problem-solving level	-	.32	.32 ⁺
	Critical-thinking disposition	-	.35	.35 ⁺
	Critical-thinking skill	.21 [*]	-	.21 ⁺

* Direct effect is significant at 0.05. ⁺ Total effect may be incomplete because of unanalyzed components

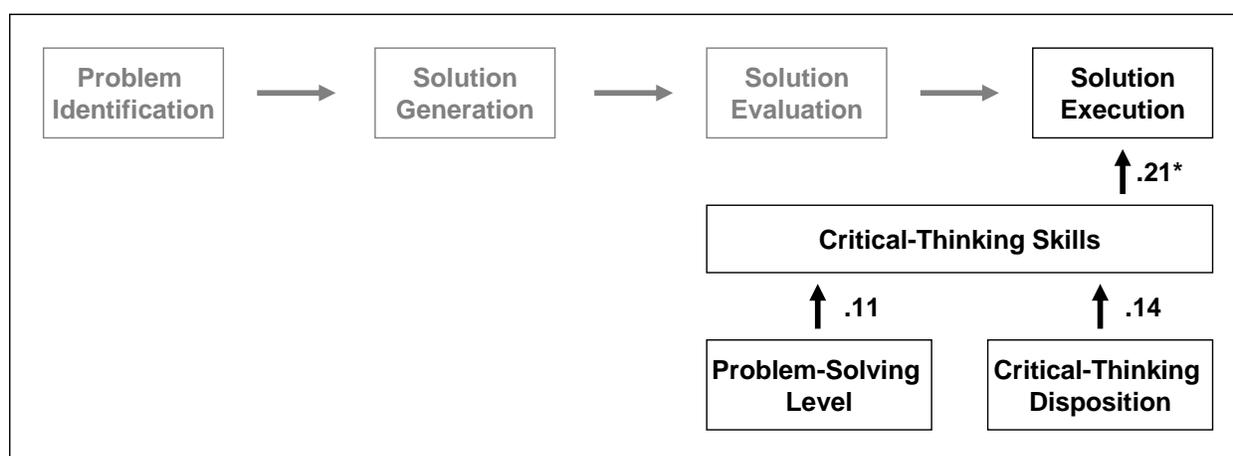


Figure 2. Revised conceptual model of cognitive factors utilized in the problem-solving process. Note. * indicates significance at 0.05. Lightened stages of problem-solving process indicate relationships that were not examined in this study.

Conclusions

Overall, students in this study were of traditional college age, mostly upperclassmen, and majoring in animal sciences and nutrition/nutritional science majors. Students' critical-thinking skill level scores, as measured via the rubric utilized in this study, ranged from a score of 18 to 48 points (M = 32.95, SD = 6.25) on the scenario based problems students were randomly assigned to solve. Students' critical-thinking dispositional scores as measured via the UF-EMI, ranged from a low of 71 to a high of 126 (M = 102.64, SD = 9.37), which was similar to findings found by developers of the instrument when administered to undergraduate students (Irani et al., 2007). With respect to problem-solving style, these students' scores ranged

between 61 and 138, indicating that this group held a variety of problem-solving styles. However, on average, problem-solving styles of these students were considered similar (M = 93.95, SD = 14.09) to the general population mean of 95 (Kirton, 2003). In terms of problem-solving level, operationalized for this study as final grade, the mean percentage was 80.98 (SD = 12.15). Among these participants, the student with the lowest final grade scored 38% and the student with the highest final grade scored 97%. On a scale of 1 to 5, students' correctness of solution in answering the Mendelian genetic problems had a mean of 2.51 (SD = 1.14). Examining these statistics, the authors concluded that there was no evidence to suggest that these undergraduate students, on average, were unusual with regard to critical-thinking skill,

critical-thinking disposition, problem-solving style, problem-solving level and ability to solve the Mendelian genetics problems.

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 ($r = .47, p < .05$) and negatively correlated with the problem-solving style efficiency construct ($r = -.35, p < .05$), suggesting that a higher critical-thinking disposition was associated with an innovative sufficiency of originality score and an adaptive efficiency score. This finding could be interpreted as a student with a preference to solve problems by generating many solutions and employing a strategy of thoroughness and attention to detail was associated with a higher critical-thinking disposition. Does this preference facilitate better critical thinking as defined by Pascarella and Terezini (1991)? Do other trait-based thinking preferences foster a higher disposition towards critical thinking? Little can be concluded until further research can confirm the UF-EMI as an accurate measure of critical-thinking disposition and determine how this disposition promotes use of critical-thinking skills.

In this study, only problem-solving level, critical-thinking disposition, and critical-thinking skill contributed to explaining the level of correctness in solutions provided by these students. Not finding significant relationships between problem-solving style and other variables in this model supports Kirton's (2003) assertion that problem-solving style is independent of level and process. However, one would find a significant relationship between problem-solving style and the solution if the answers were assessed for style as opposed to correctness. The revised model was found to be statistically significant, albeit path correlations were low. The authors conclude that the relationships between critical thinking and problem solving are less connected than previously thought. Indeed, critical thinking may not be a type of learning contributing to problem solving (Gagne, 1965) within the

cognitive domain but rather a process within the affective domain that embraces value judgments (Paul, 1985).

Recommendations and Implications

The use of a nonrandomized sample of students should give the reader caution in applying these findings beyond this intact group. There may also be limitations due to instrumentation used in this study, specifically critical-thinking disposition as this instrument is still undergoing development (Irani et al., 2007).

More research is needed to identify the relationship between problem-solving style and critical-thinking disposition as well as other trait-based preferences for cognition. If relationships are confirmed, education practitioners should be instructed how to teach students how to first, become aware of their preferences for critically thinking and second, perform outside their preferred style of thinking so that they may become better critical thinkers.

Although critical thinking and problem solving are both higher level thinking skills, this study found that critical thinking contributes little to the correctness of the final solution. More research is needed to determine whether critical thinking contributes to the other stages of the problem-solving process. Furthermore, more research is required to identify the process of critical thinking as it relates to the cognitive and affective domains of learning (Bloom, 1956). Doing such would provide teachers great insight for the purposes of providing students with curriculum and instruction that fosters both critical-thinking and problem-solving abilities.

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