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ABSTRACT

This paper describes part of a study undertaken to examine the relationship between dispositions to critical thinking, procedural knowledge in science, and formal reasoning. Three tests were administered to 346 grade 7 students at the beginning and at the end of the school year: California Critical Thinking Dispositions Inventory, Group Assessment of Logical Thinking, and Test of Integrated Process Skills II. Results indicated a possible link between scientific thinking and formal thinking but no relationship between critical thinking dispositions and formal thinking or between critical thinking dispositions and procedural knowledge in science. (Contains 7 tables, 2 figures, and 42 references.) (MKR)

An exploration of the interplay of students' dispositions to critical thinking, formal thinking, and procedural knowledge in science

by

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Introduction

In recent years, education stakeholders have shown an increasing interest in promoting the development of critical thinking. Indeed, many believe that any educational reform should include the skills, dispositions and attitudes related to critical thinking as part of the curriculum objectives (Facione, 1990). This, however, may be difficult to implement due in part to our incomplete understanding of critical thinking and of its potential relationship to other student characteristics, as well as the possibility of improving critical thinking through instruction. This paper describes part of a research project undertaken to explore some of these relationships.

In spite of the disagreement among various authors and schools of research as to the definition of critical thinking (Benderson, 1990), it can be postulated that it comprises a group of skills and dispositions, the latter being the potential, natural tendency or personal inclination to demonstrate the skills. Dispositions to critical thinking can be divided into seven categories: *truth-seeking, open-mindedness, analyticity, systematicity, self-confidence, inquisitiveness, and maturity* (Facione, 1990). The importance of dispositions as a determinant factor for critical thinking has been the subject of recent discussion among educational researchers (for example, Perkins, Thisman, Ennis, Facione & Salomon, 1994).

The relationship between critical thinking and formal operations (Inhelder and Piaget, 1955) warrants exploration. Indeed, according to Meyers (1986) and Nisbett and Ross (1980), the components of critical thinking are intrinsic to formal reasoning. Since adolescents often lack formal reasoning skills, it has been inferred that they are incapable of critical thinking. However, Keating (1988) has linked the absence of critical thinking by adolescents to a lack of content and procedural knowledge rather than a lack of the ability for formal reasoning. This opens the possibility of developing critical thinking in spite of weaknesses in formal reasoning. There seems to be a logical link between formal reasoning and critical thinking; nevertheless, it is not yet clear what relationship there is between them or the nature of the interplay, if any, of formal reasoning and dispositions to critical thinking.

A number of researchers have noted the apparent link between formal reasoning and procedural knowledge in science (Chandron, Treagust & Tobin, 1987; Harding, 1990; Niaz & Lawson, 1985; Padilla, Okey & Dillashaw, 1983; Tobin & Capie, 1981). According to some, the five operations of formal reasoning are essential skills for learning science (Bitner, 1991; Harding, 1990; Inhelder & Piaget, 1955; Lawson, 1982, 1985; Tobin & Capie, 1981) and deficiency in formal reasoning is responsible for the low results obtained in science achievement (Lawson, 1985). Others, such as Baird and Borich (1987), suggest that formal reasoning and science process skills might be two traits relating to the same cognitive structure. The ability to perform operations such as conservation, identification of variables, probabilities, proportions, combinations, and correlations have been identified as essential in order to understand scientific concepts.

The relationship of critical thinking to science learning is not clear. Some researchers view critical thinking as a domain-specific ability (Chambers, 1988; Guilbert, 1990; Kurfiss, 1988; McPeck, 1990; Paul, 1987; Swartz & Perkins, 1990); surprisingly, though, there are no definitions of critical thinking in the specific context of science learning. However, several skills, such as distinguishing a hypothesis from a problem and detecting flaws in arguments, are common to the definitions of both critical and scientific thinking as are affective dispositions such as open-mindedness and concern for accuracy (d'Angelo, 1971; Kuhn, Amsel & O'Loughlin, 1988; Munby, 1982; Siegel, 1988).

This paper describes part of a study undertaken to examine the relationship between dispositions to critical thinking, procedural knowledge in science, and formal reasoning. Because the end of elementary school and the beginning of the secondary level of education is a critical time for the development of metacognitive skills in students (Kuhn *et al.*, 1988), we have chosen to focus on this level. The dispositions and the attitudes of a student toward school, learning and science play a predominant role in science achievement (Cannon & Simpson, 1985). We feel that it is important to examine these relationships at the threshold of formal reasoning as dispositions and attitudes are developed early, resistant to change, and influence results in the cognitive domain (Bloom, 1976).

Purpose

The purpose of this study was to examine the relationship between dispositions to critical thinking, procedural knowledge in science, and formal thinking. Specifically, the following questions have been addressed:

1 - Is there a relationship between students' dispositions to critical thinking and their cognitive development?

2 - Is there a relationship between students' dispositions to critical thinking and their procedural knowledge in science?

3 - Is there a relationship between students' cognitive development and their procedural knowledge in science?

4 - Do the revealed relationships between students' dispositions to critical thinking, their cognitive development and their procedural knowledge change over time?

Method

Sample

Seven teachers were chosen from a group of New Brunswick (Canada) French-speaking

Grade 7 science teachers who had indicated their willingness to participate in the study. The selection was made based on the following factors. The teachers must have followed a total of 14 days of inservice sessions during the two years following a new science program's implementation in 1989. The teachers were from rural, suburban and urban schools, which is representative of the type of settings commonly found in the Province of New Brunswick. The ease of the researchers' access to the schools, cost factors and time constraints were also taken into consideration. The sample (N=346) included all of the Grade 7 students being taught science by the seven teachers.

Instrumentation

Three tests were administered to all the students in the sample at the beginning and at the end of the school year. Among the very few instruments for measuring critical thinking, to the best of our knowledge only one has been developed to measure affective dispositions. This test, the California Critical Thinking Dispositions Inventory (**CCTDI**; Facione & Facione, 1992) was used in our study. Based on the research by Facione (1990), it comprises 75 items to which students indicate their level of agreement or disagreement on a six-point Likert scale. The items are divided among seven subscales representing the dispositions of the critical thinker. These are: *truth-seeking* (CR), *open-mindedness* (CO), *analyticity* (CA), *systematicity* (CS), *self-confidence* (CC), *inquisitiveness* (CI), and *maturity* (CM). The maximum score for each scale is 60. According to the authors, a score lower than 40 indicates that the individual is weak in that disposition whereas someone that scores higher than 50 is strong in that disposition (Facione & Facione, 1992).

The maximum score possible on **CCTDI** is 420. According to Facione and Facione (1992), an overall score of 350 or more indicates relative strength on each of the seven subscales. A score below 280 indicates overall weak dispositions to critical thinking. This instrument has a high reported reliability.

The **GALT**, Group Assessment of Logical Thinking (Roadrangka, Yeany & Padilla, 1983), was used to assess formal reasoning. It is a 12-item test based on the six operational modes of reasoning: *conservation* (GCC), *controlling variables* (GV), and *proportional* (GPP), *probabilistic* (GPB), *correlational* (GC) and *combinatorial* (GCB) *reasoning*. This instrument is regarded as highly valid and reliable (Williams, 1989).

The **TIPS II**, Test of Integrated Process Skills II (Burns, Okey & Wise, 1985), was used to assess procedural knowledge in science. The 36-item test focuses on five integrated process skills: *identifying variables* (TV), *operationally defining* (TD), *identifying and stating hypotheses* (TH), *graphing and interpreting data* (TG), and *designing investigations* (TE). It has a high reported overall reliability.

After receiving authorization to use the tests from their respective authors, the three tests were translated from English into French and proofread by a translator. In addition, they were given to a panel of experts who reviewed them independently. Their review was meant to check for clarity, content and ease of reading. To verify the effects of translation on **GALT** and **TIPS II**, the discrimination index and the level of difficulty were computed for each item and compared to those of the instruments in their original version.

Procedure

GALT, **TIPS II** and **CCTDI** were all administered at the beginning of the school year as pre-tests to assess the students' formal reasoning, procedural knowledge in science and affective dispositions to critical thinking prior to instruction in their first science course in high school. These same tests were also administered as posttests in June to assess changes over the span of the academic year. Student participation was solicited by distributing a sheet explaining the study and asking parents to indicate their consent. The teachers administered the instruments under the supervision of one of the researchers and their involvement was limited to giving instructions and distributing questionnaires and answer sheets.

Analysis

Statistical analyses were performed using SPSS^{x} (1990). Data were first screened for missing values and outliers; means, standard deviations, frequencies and correlations were then computed for **GALT**, **TIPS II** and **CCTDI** for total scores as well as for every subscale on each of the three instruments. Inferential statistics in the form of *t-tests* were carried out to assess differences in single measures.

Principal component analysis (PCA) was performed on the subscales of the three tests to help explore if subscales would group in some structure. Variables with loadings in excess of .45 (20% overlapping variance) were kept. According to Tabachnick and Fidell (1989), "*the greater the loading, the more the variable is a pure measure of the factor*" (p. 640). After the analysis, each variable was scrutinized according to the following criteria: the communality value, the loading, the complexity, a comparison of the grouping of the variables and the theoretical underpinning.

Results

Data screening

Screening the raw data revealed problems of absenteeism and missing values. After modification, the number of students included in the analysis was 254. The majority (244) of these students were either 12 years old (81,9%) or 13 years old (14,2%) at the beginning of the school year; the remaining ten students were 14 years old

Descriptive and inferential statistics

Table I gives the statistics for the results of the pre- and posttests. For all three tests, the reliability coefficient was lower at the pre-test than the one reported in the studies and was closer to reported reliabilities at the posttest.

Insert Table I here

Dispositions to Critical Thinking

The students showed fair critical thinking dispositions with an overall mean of 290 on the pre-test and of 296 on the posttest. This score represents a significant gain (*t*(253) = 4.54, p<.001) from the beginning of the academic year.

Scores on each subscale indicate a moderate strength in each of the affective dispositions at the beginning and at the end of the year (see Figure 1). Of the seven subscales, only two averaged below the threshold score of 40. The *truth-seeking* subscale with a mean value of 36.1 and the *maturity* subscale with a mean score of 39.2 indicate weak dispositions in those areas. Although these scores were higher on the posttest, they were still the lowest with mean values of 36.5 and 40.5 respectively. The students showed strong dispositions on the *inquisitiveness* subscale at both pre- and posttests as substantiated by the highest mean values (46.8 and 47.6).

Insert Figure 1 here

Formal Reasoning

The overall mean score and standard deviation on the pre-test of **GALT** were respectively 2.87 and 1.63, and they were 4.08 and 2.18 at the posttest (Table I). These results are substantially lower than those reported in other studies (Mattheis *et al.*, 1992) for a similar population. Nonetheless, the gains made on the posttest were significant at p<.001 (*t*(253) = 10.67), and give the students an average that surpasses the one obtained by 1,358 Grade 8 students of North Carolina in the study cited previously (Mattheis *et al.*, 1992). The results also suggest that a substantial number of students advance from concrete to transitional thinkers by the end of grade seven. This finding was corroborated in a number of studies (Bitner, 1989; Mattheis *et al.*, 1992; Riley, 1988; Williams, 1989).

On **GALT**, each subscale under study contains two items. Thus, the maximum score for each item is 1 with 2 being the maximum score for each subscale. As shown in Figure 2, *combinatorial reasoning* seems to be easily attained while *correlational reasoning* seems to be the most difficult of the formal operations. Poor performance on this scale has been noted in previous studies involving middle and high school students (Bitner, 1989, 1990, 1991; Mattheis *et al.*, 1992; Shemesh, 1990; Williams, 1989), and teachers (Bitner, 1992). This pattern is also recognizable at the posttest as the mean for the two items on *correlational reasoning* did not change. Mattheis *et al.* (1992) observed that the performance of the students on the items related to this operation did not change from one year to the next, nor from one age group to the other. The results in this study are analogous to those from previous studies (Mattheis *et al.*, 1992; Williams, 1989). Roadrangka *et al.* (1983) reported similar results when validating the instrument.

Insert Figure 2 here

Procedural Knowledge in Science

The mean and standard deviation on the data for the New Brunswick students on **TIPS II** were 12.5 and 4.14 respectively at the beginning of the school year (Table I). The maximum score obtained was 25 out of a possible 36. On the posttest, the mean and standard deviation were 15.5 and 5.57 respectively, with the maximum score obtained being 33. The t-test reveals that the variation in the scores between the two administrations is significant ($t(253) = 10.09$, $p<.001$). Mattheis *et al.* (1992) reported a significant gain between the results of the seventh and eighth grade students. As was the case with **GALT**, the results are nonetheless lower than those obtained in the validation of the instruments by Burns and his colleagues (1985) and to those reported by Mattheis *et al.* (1992) for the same age group. It is worth mentioning that the results on the posttest are closer to those reported in the aforementioned studies for the same grade.

Table II shows the results on each of the subscales of **TIPS II** at the pre- and the posttests for the 254 subjects. It should be mentioned that there are a varying number of items assigned to each subscale. Thus, 12 is the maximum possible score on the *control of variables*, nine for *stating hypothesis*, six for both *operationally defining* and *interpreting data*, and three for *designing experiments*. *Designing experiments* showed the highest relative scores of all five subscales at both pre- and posttests, while *control of variables* had the lowest relative score at the pre-test and the second lowest at the posttest.

Insert Table II here

Correlations between tests

Pearson correlation coefficients between the **GALT**, **TIPS II** and **CCTDI** were computed and are shown in Table III. Correlations between the different instruments at the pre-test were relatively low. The correlation between **GALT** and **TIPS II** at the posttest was moderately strong (0.58), as one could expect from results of a number of studies (Bitner, 1989; Mattheis *et al.*, 1992; Roadrangka *et al.*, 1983). Mattheis *et al.* (1992) found correlations of .63 and .64 between the two instruments in two different populations. Baird and Borich (1987) attribute the high correlation between these two instruments to similar theoretical and/or philosophical constructs.

Insert Table III here

The intercorrelations between subscales can be found in Table IV for the pre-test and in Table V for the posttest. Moderate relationships, significant at p<.001, were found between four of the subscales of **GALT** and **TIPS II** at the posttest. These relationships were not apparent in the pre-test. Correlational values were also low between *correlational* and *combinatorial reasoning* with the other skills. If one removes the low values related to *correlational reasoning*, the correlations between the subscales of **GALT** vary from .15 to .39 at the posttest. These values are lower than those reported in the validation of the instrument by the authors (Roadrangka *et al.*, 1983). Nonetheless, they were for the most part significant at p<.001.

Insert Table IV here

Insert Table V here

Principal Component Analysis & Kaiser Varimax

A principal components analysis (PCA) was performed on the subscales from the pre-test and from the posttest taken separately. Kaiser Varimax orthogonal rotation was used due to its ability to "*simplify factors by maximizing the variance of the loadings within factors, across variables*" (Tabachnick & Fidell, 1989, p. 628), thereby facilitating interpretation.

In an attempt to strenghten the structure analysis, the same number of factors was initially envisaged for both pre-test and posttest. Although it was tempting to extract three factors, as this number coincides with the theoretical underlying constructs, trial runs suggested that more than this number was necessary, and therefore solutions were determined using Cattell's scree test for both administrations separately. As previously mentioned, the criterion for inclusion of a variable in a factor was a loading value no smaller than .45. This was done in order to maximize the f⁺ while losing the least amount of parsimony of the solution (Tabachnick & Fidell, 1989).

Table VI and Table VII show the rotated factor loadings for the pre-test and the posttest.The variables are ordered and grouped to facilitate interpretation. The rotated factor matrix gave a six-factor solution for the pre-test and accounted for 54.8 % of the variance. It gave a five-factor solution for the posttest that accounted for 58.6 % of the variance. Even with a cut of .45 for inclusion, 17 of the 18 variables loaded on at least one factor for both pre- and posttest.

Insert Table VI here

Insert Table VII here

The seven subscales of **CCTDI** loaded mainly on two factors at both pre- and posttest. Factors 1 and 2 at the pre-test were similar to factors 1 and 2 at the posttest and were well-defined by the subscales *truth-seeking* (CR), *maturity* (CM), *analyticity* (CA), *self-confidence* (CC), and *inquisitiveness* (CI). Furthermore, the structure of the loadings in both tables indicates that subscales CC, CI, CA, CR and CM loaded highly on their respective factors and communality values tended to be high.

Though the loading was moderate, *open-mindedness* (CO) loaded only with CR and CM at the pre-test while loading with CC, CI and CA at the posttest. *Systematicity* (CS) showed complexity at the posttest. The low reliabilities exhibited on subscales CO and CS at both the pre- and the posttest may explain this complex behavior. It could also indicate that the subjects achieved about the same score on these two subscales.

CR and CM loaded together on factor 2 at the posttest. Tabachnick and Fidell (1989) warn us about the reliability of a factor where only two variables load. However, since contrary to the other subscales of **CCTDI**, CR and CM did in fact correlate more with each other at both the pre-and the posttest, we can consider this factor as a reliable one.

As for the tests **TIPS II** and **GALT**, the PCA gives us a very different picture for the pre- and the posttest. For the pre-test, ten of the 11 subscales loaded on four different factors. Two of the subscales of **TIPS II** (TV, TI) loaded with *conversation* (GCC). *Control of variables* loaded moderately with GPP and GPB on factor 4. *Testing hypothesis* and *defining operationally* loaded on factor 5 while *correlational* and *combinatorial* reasoning loaded on factor 6.

Four of the five subscales of **TIPS II** loaded on one factor at the posttest. They were joined this time by *probabilistic reasoning*. Only the subscale *control of variables* (TV) loaded with two subscales of **GALT**, *control of variables* (GV) and *proportional reasoning* (GPP), indicating a possible overlap between these subscales on the two tests. *Combinatorial reasoning* and *conservation* loaded on the same factor (factor 5).

Discussion

The sample size of 254 students was relatively small considering the fact that a sample size must be large enough for reliable estimates of correlations (Tabachnick & Fidell, 1989). Though a sample of this size could be considered as only between fair and good by some authors, others suggest that this number is good considering the number of variables, the strong loadings and the fact that subjects were homogeneous (Tabachnick & Fidell, 1989). It is also worth noting that **TIPS II** and **GALT** were designed for the target population; **CCTDI** is a relatively new instrument and has been mostly used with high school and college students.

The sorted loadings at the pre- and posttests lead us to a few interesting observations. Not only was the number of factors reduced from the pre- to the posttest, but the amount of variance accounted for increased This seems to indicate that more focused and defined subsets of variables are present at the end of the school year.

The result of the PCA gives also substantial evidence for the construct validity of **CCTDI**. Whether the reliabilities were low as in the case of the pre-test or moderately high as in the case of the posttest, the subscales loaded only on two factors, independent of the subscales of **GALT** and **TIPS II**. Furthermore, the subscales of *truth-seeking* (CR) and *intellectual maturity* (CM) shared variance at both pre- and posttests. This suggests that there is a possible relationship between these variables in addition to the fact that they both are indicative of critical thinking dispositions. The same could also be said of *self-confidence* (CC), *inquisitiveness* (CI) and *analyticity* (CA). The subscale of *systematicity* (CS) illustrates complexity and its loading is also lower when compared to the other subscales. This could be due to the low reliability obtained on this subscale or, as mentioned by Tabachnick and Fidell (1989), it could indicate homogeneity in scores. The pattern exhibited by the subscales of **CCTDI** could also be the result of administering **CCTDI** to a population younger than the one for which it was originally designed. Nonetheless, the results obtained are intriguing and warrant further research.

As in other studies (Baird & Borich, 1987), our results show that there could be a degree of overlap between **GALT** and **TIPS II** suggesting that the two tests might be measuring the same traits. While other researchers have tested this hypothesis on a sample of college students, this study comes to a similar conclusion with a significantly younger population. Lawson (1985) pointed out the link between scientific thinking and formal reasoning: "*formal reasoning, as it manifests itself in performance terms, is scientific reasoning*" (p. 571). According to him, the importance of formal reasoning lies in determining the ability to generate and test hypotheses while investigating a phenomenon. From this perspective, he considers formal reasoning an excellent predictor of success in science.

The studies examined by Lawson (1985) support Inhelder and Piaget's (1955) assertion that the formal reasoning operations are interrelated. According to Lawson, the few studies that arrived at the opposite conclusion involved an insufficient number of subjects and/or a restricted range of subject performance. As previously mentioned, though the correlations between the formal operations were low, they were nonetheless significant for four of the five mental operations. *Correlational* and *combinatorial reasoning* were the variables that did not correlate to any degree with any of the variables in this study. Considering the fact that scores on the items measuring *correlational reasoning* are low in a number of studies, it is fair to assume that a closer look in the construction of these items is warranted. *Correlational reasoning* had the lowest loading factor in a single factor solution as reported by the authors of **GALT** (Roadrangka *et al.*, 1983).

The results of **TIPS II** and **GALT** in this study could add to the research done on determining if hierarchial relationships can be identified between formal operations and integrated science process skills. Some of the research reported by Yeany, Yap and Padilla in 1986 established that *combinatorial* and *conservation reasoning* together with *designing experiments* formed the base of the hierarchy of skills. These skills had to be mastered before the others could be. These researchers also concluded that *correlational reasoning* and *identifying variables* were at the top of their hierarchical model. As the results reported in Table II and Figure 2 show, the performance of the New Brunswick's students on these skills seems to concur with the results reported by Yeany *et al.* (1986).

Studies have indicated that critical thinking could be linked to formal reasoning and science process skills. For example, *open-mindedness* and *concern for accuracy* are affective dispositions that are linked to both critical thinking and learning in science (d'Angelo, 1971; Kuhn *et al.*, 1988; Munby, 1982; Siegel, 1988). The results of PCA have shown that critical thinking dispositions did not seem to form a similar theoretical construct as do process skills and formal reasoning. In fact, the traits as measured by **CCTDI** are quite different from the ones measured by **GALT** and **TIPS II**. Yet, there were significant differences between the students' performances on the three tests from the beginning to the end of the year. This raises a question as to the relationship between each subscale of **CCTDI** to those of **GALT** and **TIPS II**. Could some of the subscales of **CCTDI** be used as predictors for some of the subscales of the other two tests? However, one must keep in mind that there are many ingredients that could be making up the composite pie of factors contributing to the overall development of the students, such as teachers' characteristics, actual curriculum practice, school environment and others which were not included in this present study.

The initial results also raise numerous questions about the cause of the relatively weak performance by the New Brunswick's students on the pre-tests. Furthermore, it is apparent that there are major differences between the development of the New Brunswick's students in both reasoning and process skills at the start of the seventh grade as compared to other populations such as those in Mattheis *et al.* (1992). As suggested by these latter, elementary school science curriculum and/or quality of teachers could be some of the reasons, among numerous other factors, causing the marked differences.

Conclusion

The results of this research raise some fundamental questions as to the possible relationship between scientific thinking and formal thinking as measured by **TIPS II** and **GALT**. The factor loadings, especially at the posttest where reliability coefficients are moderate to high, indicate a possible link between the two constructs. This observation is in line with what Baird & Borich (1987) have previously suggested, that the two instruments may be measuring the same construct. It also brings support to Lawson's assertion that, in fact, scientific thinking is formal thinking (1985). Furthermore, Williams (1988) found a correlation between the number of science courses students had taken and their performance on **GALT**. Thus, our findings help underscore the need to further document the quantity and the quality of science teaching done at the Junior High level in order to examine the potential relationship between science courses and the cognitive development of the students.

The present findings do not establish any relationship between critical thinking dispositions and formal thinking, or between critical thinking dispositions and procedural knowledge in science. In fact, the results of PCA indicated that **CCTDI** measurements belong to an altogether different construct than what is measured by the two other instruments. The nature of the factor loadings of the variables of **CCTDI** also raises some challenging questions. For instance, what commonality exists between *truth-seeking* and *intellectual maturity* that would set them apart from *self-confidence*, *inquisitiveness*, and *analyticity* as suggested by the loadings of these variables? At first glance, the clustering of five of the seven variables of **CCTDI** seems to imply that we are in the presence of two different constructs underlying variability. Furthermore, there is the possibility of the existence of a psychological underpinning between being "intellectually mature" and "truth-seeking"; is there also one between having self-confidence, being curious and having an analytical mind? It would thus seem appropriate to further research this behaviour as it could lead to the naming of new subsets of constructs within critical thinking dispositions, thus identifying them substantially. Similarly, it would refine the operational definition of critical thinking dispositions.

It might also be of value to investigate the results that indicated that the profiles in critical thinking dispositions of the grade 7 students were similar to those shown by college freshmen students in the study done by Facione, Sánchez & Facione (1994). For example, both samples had comparable weak dispositions on the scale of *truth-seeking* while showing strong dispositions on the scales of *open-mindedness* and *curiosity*. Were these results similar because these scales reflect basic human tendencies or because previous schooling of college freshmen has not resulted in a change in the affective dispositions? This raises the need to further document the factors that are conducive to the development of favorable dispositions.

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References

Baird, W.E. & Borich, G.D. (1987). Validity considerations for research on integrated-science process skills and formal reasoning ability. *Science Education, 71*(2), 259-269.

Benderson, A. (1990). Critical thinking : Critical issues. *Focus, 24*.

Bitner, B.L. (1989). *Developmental patterns in logical reasoning of students in grades six through ten: Increments and plateaus.* Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, San Francisco CA, March 30 - April 1. (ERIC Reproduction Document Service ED 306 092)

Bitner, B.L. (1990). *Thinking processes model: Effect on logical reasoning abilities of students in Grade six through twelve.* Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, Atlanta, GA, April 8-11. (ERIC Reproduction Document Service ED 322 009)

Bitner, B. L. (1991). Formal operational reasoning modes : Predictors of critical thinking abilities and grades assigned by teachers in science and mathematics for students in grades nine through twelve. *Journal of Research in Science Teaching*, *28*(3), 265-274.

Bitner, B.L. (1992). *Preservice elementary and secondary science methods teachers: Comparison of formal reasoning, ACT science, process skills, and physical science misconceptions scores*. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, Boston, MA, March 23-24. (ERIC Reproduction Document Service ED 344 781)

Bloom, B. S. (1976). *Human characteristics and school learning*. New York : McGraw-Hill Book Company.

Burns, J. C., Okey, J. R. & Wise, K. C. (1985). Development of an integrated process skill test : TIPS II. *Journal of Research in Science Teaching*, *22*(2), 169-177.

Cannon, R. K. & Simpson, R. D. (1985). Relationships among attitude, motivation, and achievement of ability grouped seventh-Grade life science students. *Science Education*, *69*(2), 121-138.

Chambers, J. H. (1988). Teaching thinking throughout the curriculum - Where else? *Educational Leadership*, *45*(7), 4-6.

Chandron, S., Treagust, D. S. & Tobin, K. (1987). The role of cognitive factors in chemistry achievement. *Journal of Research in Science Teaching*, *24*(2), 145-160.

d'Angelo, E. (1971). *The teaching of critical thinking*. Amsterdam : B.R. Grüner N.V.

Facione, P. A. (1990). *Critical thinking: A statement of expert consensus for purposes of educational assessment and instruction. Research findings and recommendations*. American Philosophical Association, Newark, DE. (ERIC Document Reproduction Service No. ED 315 423)

Facione, P.A. & Facione, N.C. (1992). *The California Critical Thinking Dispositions Inventory*. Millbrae, CA : The California Academic Press.

Facione, P.A , Sánchez, C.A. & Facione, N.C. (1994). *Are college students disposed to think?* Paper presented at the Annual Meeting of the American Educational Research Association, New Orleans.

Gu[illegible]ert, [illegible] (199[illegible]). La pensée critique en sciences : Présentation formelle d'un modèle iconique en v[illegible] d'une définition formelle opérationnelle. *The Journal of Educational Thought*, *24*(3), 19[illegible]

Harding, A. (1990). *The relationship of logical thinking and disembedding ability to a conceptual shift using a physical science concept.* (Doctoral dissertation, Ohio State University). (ERIC Document Reproduction Service No. ED 325 330)

Inhelder, B. & Piaget, J. (1955). *De la logique de l'enfant à la logique de l'adolescent : Essai sur la construction des structures opératoires formelles.* Paris : Presses Universitaires de France.

Keating, D. P. (1988). *Adolescents' ability to engage in critical thinking.* Madison, WI . National Center on Effective Secondary Schools. (ERIC Document Reproduction Service No. ED 307 508)

Kuhn, D., Amsel, E. & O'Loughlin, M. (1988). *The development of scientific thinking skills.* San Diego, CA : Academic Press Inc.

Kurfiss, J. (1988). *Critical thinking : Theory, research practice and possibilities. Association for the study of higher education.* Washington, DC : ERIC Clearinghouse on Higher Education. (ERIC Document Reproduction Service No. ED 304 041)

Lawson, A. E. (1982). Formal reasoning, achievement, and intelligence: An issue of importance. *Science Education, 66*, 77-83.

Lawson, A. E. (1985). A review of research on formal reasoning and science teaching. *Journal of Research in Science Teaching, 22*(7), 569-617.

Mattheis, F., Spooner, W. E., Coble, C. R., Takemura, S., Matsumoto, S., Matsumoto, K. & Yoshida, A. (1992). A study of the logical thinking skills and integrated process skills of Junior High school students in North Carolina and Japan. *Science Education, 76*(2), 211-222.

McPeck, J. E. (1990). *Teaching critical thinking: Dialogue and dialectic.* New York : Routledge, Chapman and Hall, Inc.

Meyers, C. (1986). *Teaching students to think critically.* San Francisco, CA : Jossey-Bass Inc. Publishers.

Munby, H. (1982). *What is scientific thinking?* Ottawa : Science Council of Canada. (ERIC Document Reproduction Service No. ED 218 139)

Niaz, M. & Lawson, A. E. (1985). Balancing chemical equations: The role of developmental level and mental capacity. *Journal of Research in Science Teaching, 22*(1), 41-51.

Nisbett, R. E. & Ross, L. (1980). *Human inference : Strategies and shortcomings of social judgment.* Englewood Cliffs, NJ : Prentice-Hall Inc.

Padilla, M. J., Okey, J. R. & Dillashaw, F. G. (1983). The relationship between science process skills and formal thinking ability. *Journal of Research in Science Teaching*, *20*(3), 239-246.

Paul, R. W. (1987). Dialogical thinking : Critical thought essential to the acquisition of rational knowledge and passions. In J. B. Baron and R. J. Sternberg (Eds.), *Teaching thinking skills: Theory and practice*. New York : W. H. Freeman and Company.

Perkins, A, Thisman, S., Ennis, R., Facione, P. & Salomon, G. (1994). *Beyond abilities: An investigation of the dispositional side of thinking*. Joint presentation at the Annual Meeting of AERA, New Orleans, LA, April.

Riley, J.P. (1988). *Analysis of data for the GALT test in a study of students in the Philippines and Indonesia.* Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, Lake of the Ozarks.

Roadrangka, V., Yeany, R. H. & Padilla, M. J. (1983, April). *The construction and validation of group assessment of logical thinking (GALT).* Paper presented at the annual meeting of the National Association for Research in Science Teaching, Dallas, TX.

Shemesh, M. (1990). Gender-related differences in reasoning skills and learning interests of Junior High school students. *Journal of Research in Science Teaching*, *27*(1), 27-34.

Siegel, H. (1988). *Educating reason: Rationality, critical thinking and education.*. London : Routledge Inc.

SPSS Inc. (1990). *SPSS^x Statistical Algorithms*. Chicago: SPSS Inc.

Swartz, R. J. & Perkins, D. N. (1990). *Teaching thinking : Issues and approaches*. Pacific Grove, CA : Midwest Publications, Critical thinking and software.

Tabachnick, B.G. & Fidell, L.S. (1989). *Using multivariate statistics, second edition.* New York, NY: HarperCollins*Publishers*, Inc.

Tobin, K. G. & Capie, W. (1981). The development and validation of a group test of logical thinking. *Educational and Psychological Measurement*, *41*(2), 413-423.

Williams, R. L. (1989). *A comparative study of logical thinking skills : West German data.* Paper presented at the annual conference of National Association for Research in Science Teaching, San Francisco, CA. (ERIC Document Reproduction Service No. ED 305 249)

Yeany, R. H., Yap, K. C. & Padilla, M. J. (1986). Analyzing hierarchial relationships among modes of cognitive reasoning and integrated science process skills. *Journal of Research of Science Teaching*, *23*(4), 277-291.

Table I Means and standard deviations on each test for N=254

Test		Mean	Standard deviation	Lowest score	Highest score	Reliability α
CCTDI	pre	290	18.7	244	338	.71
	post	296	24.8	242	381	.84
GALT	pre	2.87	1.63	0	9	.45
	post	4.08	2.18	0	11	.63
TIPS II	pre	12.5	4.13	2	25	.53
	post	15.5	5.57	5	33	.74

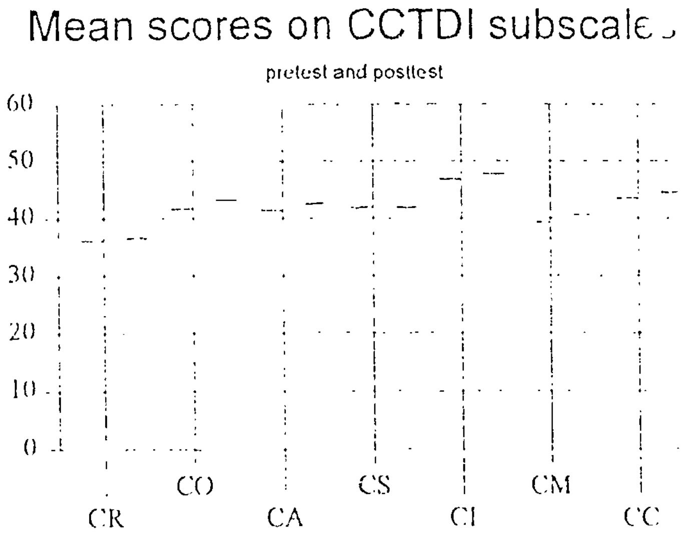
Mean scores on CCTDI subscales
pretest and posttest
60
50
40
30
20
10
0
CR
CO
CA
CS
CI
CM
CC

Figure 1

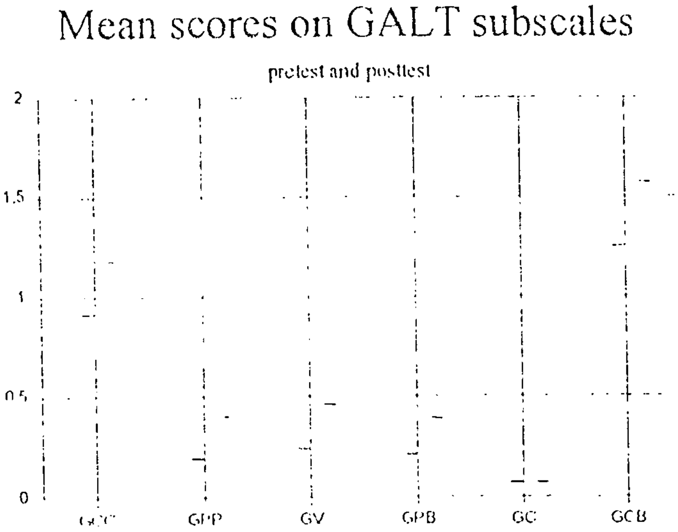
Mean scores on GALT subscales
pretest and posttest
2
1.5
1
0.5
0
GCC
GPP
GV
GPB
GC
GCB

Figure 2

Table II Descriptive statistics for each subscale of TIPS II for N=254

Subscale	Means		Standard deviation	
	pre	post	pre	post
Control & identify variables	3.87	4.85	1.81	2.15
Stating hypothesis	3.07	3.54	1.53	1.93
Operationally defining	2.08	2.69	1.47	1.43
Designing experiment	1.40	1.54	0.94	0.96
Graph & interpret data	2.05	2.85	1.39	1.64

Table IIICorrelations between tests. N=254

Test	CCTDI (pre)	GALT (pre)	TIPS II (pre)	CCTDI (post)	GALT (post)	TIPS II (post)
CCTDI (pre)	1.00	0.20	0.39	0.55	0.25	0.41
GALT (pre)		1.00	0.39	0.25	0.58	0.43
TIPS II (pre)			1.00	0.39	0.47	0.56
CCTDI (post)				1.00	0.35	0.44
GALT (post)					1.00	0.58
TIPS II (post)						1.00

Table IV Intercorrelations among CCTDI, TIPS II and GALT subscales at the pre-test

	CCTDI							TIPS II					GALT					
	1 CR	2 CO	3 CA	4 CS	5 CC	6 CI	7 CM	8 TV	9 TD	10 TII	11 TG	12 TE	13 GCC	14 GPP	15 GV	16 GPB	17 GC	18 GCB
1	1.00	.21	-.25	.22	-.24	-.06	.51	.09	-.03	.02	.19	.13	.05	-.10	-.05	-.02	-.08	.06
2		1.00	.14	.27	.12	.20	.31	.13	.23	.12	.11	.21	.09	.10	.18	.10	.05	.15
3			1.00	.20	.39	.33	-.03	.07	.24	.17	.11	.23	.02	.15	.03	.15	-.15	.08
4				1.00	.21	.25	.33	.14	.13	.05	.18	.22	.05	.13	.11	.04	-.11	.06
5					1.00	.34	-.14	.08	.19	.13	.04	.07	.05	.13	.07	-.05	-.09	.14
6						1.00	.07	.03	.17	.04	.10	.13	-.07	.12	.09	.05	-.06	.06
7							1.00	.09	.13	.10	.18	.22	.14	.08	.05	.15	-.09	.11
8								1.00	.14	.00	.18	.19	.14	.12	.05	.17	-.05	.14
9									1.00	.26	.15	.22	.14	.02	.08	.16	-.01	.19
10										1.00	.20	.15	.11	.15	.06	.14	-.06	.16
11											1.00	.20	.18	.07	.07	.22	.06	.09
12												1.00	.23	.17	.02	.25	-.05	.13
13													1.00	.17	-.01	.17	-.06	.22
14														1.00	.13	.22	.01	.05
15															1.00	.17	-.01	.04
16																1.00	.06	.16
17																	1.00	.12
18																		1.00

Table V Intercorrelations among CCTDI, TIPS II and GALT subscales at the posttest

	CCTDI							TIPS II					GALT					
	1 CR	2 CO	3 CA	4 CS	5 CC	6 CI	7 CM	8 TV	9 TD	10 TH	11 TG	12 TE	13 GCC	14 GPP	15 GV	16 GPB	17 GC	18 GCB
1	1.00	.28	.08	.35	-.15	.07	.58	.10	.24	.26	.22	.21	.10	.06	.29	.20	-.13	.17
2		1.00	.42	.38	.29	.48	.43	.12	.13	.28	.24	.26	.10	.19	.15	.21	.06	.20
3			1.00	.43	.59	.41	.24	.18	.23	.28	.32	.32	.07	.25	.15	.30	.12	.13
4				1.00	.27	.37	.41	.23	.11	.18	.21	.18	.09	.18	.20	.19	-.06	.08
5					1.00	.47	.07	.18	.08	.12	.16	.20	.04	.16	.06	.17	.17	.09
6						1.00	.26	.07	.01	.15	.21	.24	-.02	.09	.06	.12	.03	.14
7							1.00	.13	.26	.33	.27	.29	.21	.13	.21	.23	.10	.18
8								1.00	.28	.21	.26	.15	.21	.23	.35	.22	.03	.13
9									1.00	.35	.42	.38	.24	.24	.32	.25	.11	.04
10										1.00	.48	.45	.16	.29	.34	.40	.02	.21
11											1.00	.46	.30	.29	.32	.46	.12	.29
12												1.00	.16	.18	.25	.29	.03	.12
13													1.00	.29	.20	.20	.05	.24
14														1.00	.36	.38	.09	.17
15															1.00	.39	.03	.15
16																1.00	.19	.22
17																	1.00	.04
18																		1.00

Table VI Factor loadings, communalities (h^2) for CCTDI, GALT and TIPS II subscales for PCA and varimax rotation

Pre-test Subscale	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**	**Factor 6**	h^2
CC	.76						.62
CI	.69						.53
CA	.67						.57
CM		.78					.66
CR		.77					.73
CS		.56					.56
CO		.54					.51
TV			.60				.50
TE			.53				.41
GCC			.67				.49
TG							.28
GV				68			.56
GPP				61			.51
GPB				.57			.54
TH					81		.69
TD					.55		.50
GC						.78	.68
GCB						55	.53

Table VII Factor loadings, communalities (h^2) for CCTDI, GALT and TIPS II subscales for PCA and varimax rotation

Posttest Subscale	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**	h^2
CC	.79					.73
CI	.76					.61
CA	.75					.67
CO	60					59
CS	54	.50				.65
CR		.83				76
CM		69				68
TE			.74			61
TD			.69			.56
TH			67			.54
TG			.66			60
GPB			.47			.48
TV				.73		.57
GV				.62		.54
GPP				.55		.50
GCB					.75	.61
GCC					.55	.45
GC						.42