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Seventh Graders' Academic Achievement, Creativity, and Ability to Construct a Cross-domain Concept Map — A Brain Function Perspective

ABSTRACT This study proposes an interactive model of *cross-domain* concept mapping with an emphasis on brain functions, and it further investigates the relationships between academic achievement, creative thinking, and cross-domain concept mapping. Sixty-nine seventh graders participated in this study which employed two 50-minute instructional sessions. The findings suggest that (a) the seventh graders may lack the awareness or ability to integrate knowledge and make connections between their learning and life experiences; (b) creative thinking, academic learning and concept mapping share similar capacities; and (c) cross-domain concept mapping, which fosters cross-domain information integration and connections between learning and life experiences, can be an efficient mental tool in understanding a student's creative thinking and academic learning.

INTRODUCTION

Concept mapping enables teachers to gain invaluable insights into the cognitive modes of their students (Kinchin, Hay, & Adams, 2000). The technique has therefore been widely used since the 1980s in an attempt to better comprehend differences in student construction of knowledge and subsequent learning enhancements (e.g. Anderson, 1985; Santhanam, Leach, & Dawson, 1998; Elhelou, 1997; McClure, Sonak, & Suen, 1999; Okebukukola & Jegede, 1988). While examining the relationships between concept mapping and its correlates, most prior studies have focused on the construction of domain-specific concept maps, rather than on those which are cross-domain (e.g., Baroody, Bartels, 2000; Bolte, 1999; Guastello, Beasley, & Sinatra, 2000; Kinchin, 2000; Nicoll, Francisco, & Nakhleh, 2001; Sungur, Tekkaya, & Geban, 2001). "Cross-domain" concept mapping encourages learners to integrate knowledge from a wide range of disciplines, making meaningful learning more possible. This study therefore focuses on cross-domain concept mapping.

Although few studies have been undertaken to investigate the relationship between concept mapping and creative thinking, some research findings indicate that high-achievers construct better concept maps than do low-achievers (Lian, 1998). One question that arises is whether this finding still holds true when cross-domain concept maps are constructed. Therefore, this study tries to propose a model in which the connections among academic competencies, creative thinking skills, and concept mapping abilities are identified from the perspective of brain functions. Moreover, this study seeks to clarify whether students with differing capacities for academic achievement and creativity actually perform differently when constructing a cross-domain concept map.

ACADEMIC ACHIEVEMENT, CREATIVITY, AND CONCEPT MAPPING

The Function and Instruction of Concept Mapping

A concept map is a drawn picture, or representation, that reflects a learner's understanding and interpretation of various aspects of a given topic (Raymond, 1997). In concept mapping, key ideas are represented as nodes that are linked by different types of pathways or relationships (Holley & Dansereau, 1984). Based on Ausubel's assimilation theory of cognitive learning, concept mapping requires that cognitive structures be organized hierarchically, with new concepts being subsumed under more inclusive ones. When learners arrange newly-acquired knowledge in such a ranked fashion and explore the possible linkages between various notions, meaningful learning occurs (as cited in Novak & Gowin, 1984). Accordingly, concept maps provide learners not only with summarized information that contributes to learning but also with a framework that helps when systematizing materials in a particular knowledge domain (Alvermann, 1986; Moore & Readence, 1984; Novak, 1984; Novak & Gowin, 1984; Stewart, 1984).

Many studies have found that the teaching of concept mapping augments students' meaningful learning (e.g. Anderson-Inman & Zeitz, 1993; Santhanam et al., 1998; Elhelou, 1997; Lian, 1998; McClure et al., 1999; Rafferty & Fleschner, 1993). As to which approach to teaching concept mapping leads to a better learning effect, Anderson-Inman and Zeitz (1993) found that students benefited the most when they created their own maps throughout the learning process. In such a student-created concept mapping process, learners are more likely to become earnestly involved learners (Anderson-Inman & Zeitz, 1993). This study therefore employs a "student-created map" approach in the experimental instruction phase.

When teaching students to make a concept map, the following five steps are commonly recommended (Clark, 1990; Rafferty & Fleschner, 1993): (a) identifying the major concepts; (b) placing the concepts on paper from the most inclusive (abstract) to the most specific (concrete); (c) linking the concepts and labeling each link; (d) branching out from each concept to include definitions, illustrations, and factual evidence; and (e) using cross-links to create and analyze additional relationships. This study employs this five-stage approach in teaching concept mapping.

Academic Abilities and Cross-domain Concept Mapping

Earlier research results (Lian, 1998) have suggested that low-achievers benefit more from the instruction of concept mapping than do high-achievers, whereas high-achievers make better concept maps than do low-achievers. Unlike most other researchers (e.g., Anderson-Inman & Zeitz, 1993; Clark, 1990; Santhanam et al., 1998; Elhelou, 1997; Lian, 1998; McClure et al., 1999; Rafferty & Fleschner, 1993), here I attempt to analyze the relationships between academic ability and concept mapping by incorporating brain functions and process-information theory.

The brain's structural capacity for establishing patterns and the mind's processing capacity for expressing complex interrelationships in networks of knowledge are dramatically under-represented. Current brain research has provided a wealth of insight into how the brain passively takes in and actively processes information (Hyerle, 1996, 2000). The findings suggest that the brain serves as a pattern detector, with the mind playing the role of organizer to classify data into schematic patterns and that students inherently seek patterns in nature (Caine & Caine, 1994, 1995; Freeman, 1995; Hyerle, 2000; Jensen, 1998; Mehler & Dupoux, 1994). From the perspective of the information process model, the importance of these implications cannot be overemphasized because in this model, three kinds of memories are fundamental in learning: sensory memory, short-term memory (working memory), and long-term memory (Eggen & Kauchak, 2001). Students' actively seeking patterns fortifies their filtering of information from sensory memory to their short-term memory. In the meantime, their actively detecting patterns in the working memory helps students organize information into schematic patterns, which further contributes to the construction of integrated knowledge in their long-term memory. These mechanisms of the brain are fundamental to cross-domain concept mapping.

During *cross-domain* concept mapping, students first, need to retrieve topic-related information from the long-term memory in order to come up with as many concepts, definitions, illustrations, and as much factual evidence as possible. Such information is derived from both domain knowledge and cross-domain knowledge. Then, students seek and detect patterns among the retrieved information and represent them in logical hierarchies and classifications. Next, they make reasonable connections among the concepts, definitions, illustrations, and factual evidence. Besides this, the predisposition to actively seek and the strategies used to detect patterns as well as the use of concept mapping help students organize newly and formerly acquired information into schematic patterns that make sense to them. In brief, concept mapping allows for flexibility in students' formation of cognitive patterns.

How concept mapping helps the mind organize new input into schematic patterns can be explained by the fact that schemata are often networks of information categories and that visual representations complement the structured patterning of neural networks and the internalized schematic structures of concepts (Hyerle, 2000). Piaget's ideas of assimilation and accommodation also lend considerable support for the mind's capacity to organize existing schemata and to reconstruct schematic patterns (Eggen & Kauchak, 2001). Simply put, concept maps serve as a bridge between patterns in the mind and the outward representation of these patterns.

Therefore, the process of learning and that of making cross-domain concept maps equally require certain abilities, and high-achievers should, to some degree, know how to apply such abilities. This accounts for the fact that even though high-achievers do make better concept maps, they do not benefit as much as low-achievers from concept mapping instruction. In other words, high-achievers may in fact be classified as such because they may well have become accustomed to seeking patterns of information, become effective in detecting patterns and experienced in organizing information into schematic patterns. Such ability may further lead to more effective accessibility to knowledge and a greater degree of information processing. Other learning abilities, such as those related to generating new models and redesigning older ones as well as the assimilation and accommodation of new input may quite likely influence how a student makes propositions, hierarchies, cross-links, and examples while creating a concept map. As might not be surprising then, high-achievers should exhibit more elaborate and integrated knowledge representations than do low-achievers when concept mapping.

Creative Thinking Skills and Cross-domain Concept Mapping

Though only a few studies have been conducted to examine the relationship between creative thinking and concept mapping (Flower & Hays, 1984; Russell & Meikamp, 1994; Wandersee, 1990), existing research findings tend to suggest that creative thinking and concept mapping are correlated. To cite one example, Russell and Meikamp (1994) found that creativity training contributed to students' development of concept mapping and they postulated that concept mapping is a metacognitive strategy that allows students to integrate a variety of creative relationships among a wide range of concepts. In line with this, Flower and Hays (1984) expanded upon this notion by reporting writers actually do use concept mapping as an organizational tool for the purposes of brainstorming.

When it comes to how creative thinking and concept mapping are related to each other, Robinson (1982) asserted that a concept map acts as a classroom mirror, reflecting the fluency, flexibility, and originality of a student's thinking. Wandersee (1990) claimed that cartography links perception, interpretation, cognitive transformations, and creativity. He illustrated his belief in the basic purposes of map-making by stating they are four-fold: to challenge one's assumptions, to recognize new patterns, to make new connections, and to visualize the unknown. Similarly, Clark (1990) held that concept maps let one create mental models of basic ideas and processes. Gradually, the mind works to subsume or incorporate specific information within the structures of previously organized schemata, hence continually changing the way one thinks. It therefore seems justifiable to claim that concept maps can be effective not only in constructing and reforming interrelated knowledge, but also in discovering and rediscovering information lost in the recesses of the mind.

More specific explanations to account for the relationships between creativity and concept mapping may be found in a recently proposed approach to creativity — the Creative Cognition Approach (Ward, Smith, Finke, 1999). This approach focuses on the studies of insight, the extension of concepts, recently activated knowledge, conceptual combinations, and creative imagery. According to the Geneplore Model — one of the creative cognition approaches — when creating, one alternates between generative and exploratory processes, refining the structures depending upon the demands or constraints of the particular task. Common types of generative processes are: (a) the retrieval of existing structures from memory; (b) the formation of simple associations among the structures or combinations therein; (c) the mental syntheses of new structures; (d) the mental transformation of existing structures into forms; and (e) the analogical transfer of information from one domain to another categorical reduction (Ward et al., 1999). The thinking processes here are parallel to those of concept mapping, and the abilities required in the generative process are evidently related to the skills of making propositions, ordering hierarchies, forming cross-links, and formulating examples when concept mapping. Moreover, the analogical transfer of information from one domain to another is especially important to cross-domain concept mapping.

The most significant difference between a *cross-domain* concept map and one that is *domain-specific* must obviously lie in the "cross-domain knowledge" component; cross-domain concept mapping necessitates the use of interdisciplinary knowledge. Creativity requires both domain-specific and cross-domain knowledge for one to avoid rigidity and to be better equipped to come up with novel ideas (Amabile, 1988; Feldhusen, 1995; Runco & Walberg, 1998). Csikzsenmihalyi and Sawyer (1993) have strongly emphasized the importance of cross-domain knowledge in the process of creativity and have devised a creativity process model based on the aspects of problem discovery and problem solving. They claimed that inputs from different domains are essential to problem identification and that the syntheses of such inputs will further influence insight formation and resolution evaluation. It can therefore be reasoned that creative thinking and concept mapping involve similar thinking processes, and that the abilities underlying creativity most probably provide the basis for effective cross-domain concept mapping.

Interactive Model of Cross-domain concept Mapping

The relationships among academic abilities, creative thinking skills, brain functions, information-processing theory, and cross-domain concept mapping are depicted in Figure 1. A cross-domain concept map involves attitudes, strategy, and knowledge. The attitudes toward and the strategies used in actively detecting patterns and organizing information into schematic patterns are consistent with brain functions. In interacting with the three types of memories, the three compo-

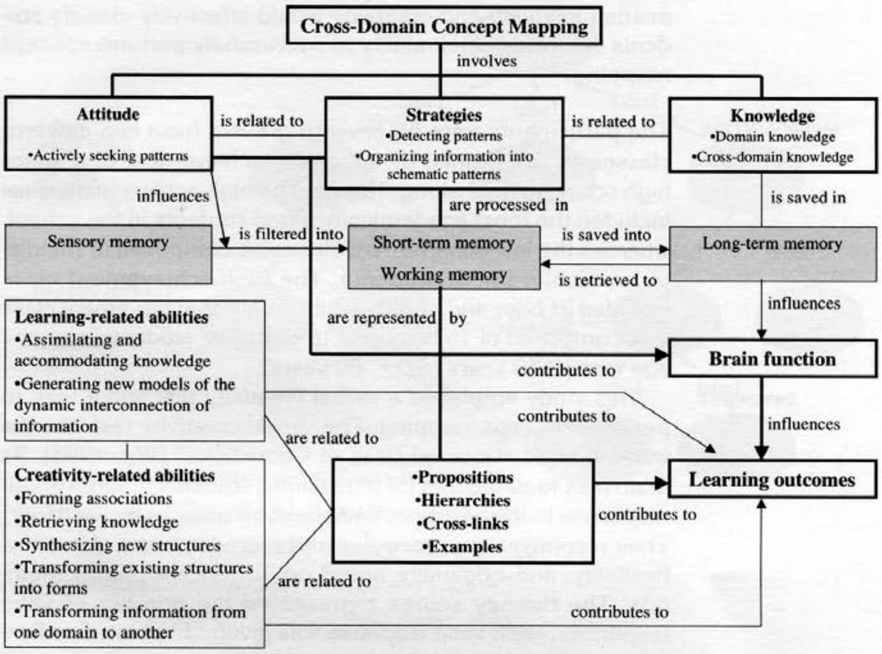

FIGURE1. Interactive model of concept mapping, academic abilities, and creative thinking skills — a brain function perspective.

nents of concept mapping are finally integrated and represented by the creation of propositions, hierarchies, cross-links, and examples. Obviously, these skills are closely related to academic-learning and creativity abilities. It follows that forming cross-domain maps requires the optimal functioning of the brain and this further improves learning outcomes.

HYPOTHESES

This study put forth three hypotheses. For one, academic abilities would have effects on the performance of concept mapping; more specifically, high-achievers would construct better concept maps than would low-achievers. Second, the abilities involved in creative thinking and those in concept mapping would be significantly correlated. In other words, the greater the degree of fluency, flexibility, and originality students have, the more valid propositions, hierarchies, cross-links, and examples they would make. The third hypothesis was that academic ability and creativity would be effective predictors of ability-group membership based on concept mapping; that is, academic ability and creativity would effectively classify students in terms of their ability to successfully perform concept mapping.

METHODOLOGY

Participants

The participants were 69 seventh graders from two different classes as determined by academic achievement at a junior high school in Kaohsiung, Taiwan. The high-achievement class included the most academically gifted students in the school, whereas the low-achievement class was composed of middle- to low-achievement students. The high-achievement class included 21 boys and 17 girls, while the lower-achievement class was comprised of 15 boys and 16 girls. The students' average age was 12.40 years (*SD* = .60 years).

Instruments

This study employed a verbal creativity test and a task to perform concept mapping. The verbal creativity test was the well-validated "Unusual Uses of Chopsticks" (Wu, 1998). Its main task required that for ten minutes students thought about responses to the question, "What can chopsticks be used for?" Their responses were recorded and scored in terms of fluency, flexibility, and originality based on Torrance's (1966) methods. The fluency scores represented the number of valid responses; each valid response was given "1" point. The flexibility score indicated valid response categories. Responses were grouped into categories and each different category was counted as one point. Finally, the originality score revealed the degree of novelty of the valid responses; each response was given "0", "1", or "2" point(s) based on a scoring norm of 2300 students.

For the measure of concept mapping, the students were asked to create their own concept map within 20 minutes using "school violence" as the topic. This topic is viewed as cross-domain because it requires students to make use of knowledge from a variety of sources rather than a single course domain such as science, mathematics or history. The scoring criteria for this followed the Novak and Gowin (1984) and McClure et al's (1999) methods. Figure 2 provides an example of the means of scoring the maps in this study. Each concept map was scored by two trained graduate students who mutually agreed on each evaluation. The scored abilities in concept mapping were propositions, hierarchies, cross-links, and examples, and their scoring weights were 1, 5, 10, and 1, respectively. The total score for a concept map was the weighted composite score of these four abilities.

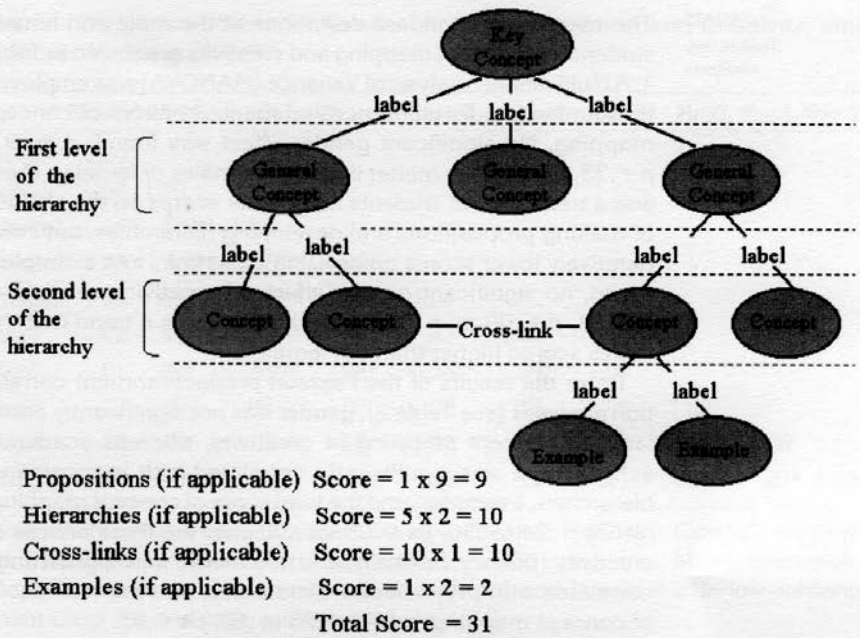

FIGURE 2. Example of how a concept map was scored.

Procedures

Both classes received two 50-minute instruction sessions by the researcher. The instructional goal was for students to understand what creativity and concept mapping are, and how a concept map is made. The teaching activities and time distribution were as follows: (a) Introduction to the concepts of creativity: 5 minutes; (b) Employment of the creativity test: 10 minutes; (c) Introduction to what a concept map is and how it is constructed: 15 minutes. (Here, "key words" — a mnemonic device in Chinese — were used to help students memorize the steps of concept mapping. At this stage, a concept map concerning "the protection of wild animals" was presented as an illustration); (d) Practice with a task involving concept mapping in small groups of 4 or 5: 30 minutes. (The topic used for the practice was "Junior school students don't like mathematics"); (e) Group analysis of the strengths and weaknesses of each concept map developed by the groups: 10 minutes; and (f) Performance involving an assigned topic for individual concept mapping: 30 minutes. (The assigned topic was "school violence.")

RESULTS
Preliminary analyses

The means and standard deviations of the male and female students on concept mapping and creativity are shown in Table 1. A Multivariate Analysis of Variance (MANOVA) was employed to examine gender differences on the four indices of concept mapping. No significant gender effect was found, $\Lambda = .93$, $p = .33$, $\eta^2 = .07$. No matter if they were males or females, there was a trend that all students had higher scores on the abilities of making propositions and developing hierarchies, but comparatively lower scores on devising cross-links and examples. Again, no significant gender effect on creativity was found, $\Lambda = .91$, $p = .09$, $\eta^2 = .09$. However, there was a trend that the males scored higher than the females.

From the results of the Pearson product-moment correlation analyses (see Table 2), gender was not significantly correlated to concept mapping or creativity, whereas academic achievement was significantly correlated with propositions, hierarchies, examples, and the total score of concept mapping, $rs(67) = .24$ to $.56$, $ps < .05$. In addition, the three indices of creativity (fluency, flexibility, and originality) were significantly correlated with propositions, hierarchies, and the total score of concept mapping, $rs(67) = .28$ to $.60$, $ps < .05$.

TABLE 1. Means and Standard Deviations of Male and Female Students on Concept Mapping.

Test	Males (n = 36)		Females (n = 33)		Total (N = 69)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Concept Mapping						
Propositions	20.39	10.36	20.03	7.28	20.22	8.96
Hierarchies	15.28	5.73	15.15	4.92	15.22	5.32
Cross-links	5.28	10.28	10.91	14.87	7.97	12.90
Examples	.39	1.59	1.03	3.40	.70	2.62
Total score	41.33	19.99	47.12	18.99	44.10	19.60
Creativity						
Fluency	15.86	10.10	13.09	6.83	14.54	8.74
Flexibility	8.64	3.91	6.97	3.06	7.84	3.60
Originality	13.00	11.96	8.85	7.97	11.01	10.39

TABLE 2. Correlation Matrix for Gender, Academic Achievement, Creativity, and Concept Mapping ($N = 69$).

	Gender[a]	Ach[b]	Create1	Create2	Create3	Map1	Map2	Map3	Map4	Map_T
Gender	1.00									
Ach	−.07	1.00								
Create1	−.16	.67***	1.00							
Create2	−.23	.71***	.88***	1.00						
Create3	−.20	.60***	.93***	.80***	1.00					
Map1	−.02	.56***	.56***	.60***	.47***	1.00				
Map2	−.01	.26*	.38**	.28*	.36**	.39***	1.00			
Map3	−.22	−.10	.04	−.07	−.08	.17	.09	1.00		
Map4	.12	.24*	.13	.06	.08	.25*	−.03	.04	1.00	
Map_T	.15	.30*	.35**	.31**	.28*	.71***	.51***	.77***	.27*	1.00

Note: Ach: achievement; Create1: fluency; Create2: flexibility; Create3: originality; Map1: propositions; Map2: hierarchies; Map3: cross-links; Map4: examples; Map_T: total score of concept map. a: male = 1 and female = 2. b: low-achievement class = 1 and high-achievement class = 2.

* $p < .05$. ** $p < .01$. *** $p < .001$.

Academic Achievement and Concept Mapping

Table 3 shows the means and standard deviations of the high-achievers and low-achievers on concept mapping. "High-achievers" versus "low-achievers" reflects the class they were recruited from. When a MANOVA was performed to test the effects of academic achievement on concept mapping, the analysis yielded a significant effect, $\Lambda = .63$, $p = .000$, $\eta 2 = .37$.

TABLE 3. Means and Standard Deviations of High-Achievers and Low-Achievers with Regard to Concept Mapping.

Test	High Achievers ($n = 38$)		Low Achievers ($n = 31$)	
	M	*SD*	*M*	*SD*
Propositions	24.74	8.64	14.68	5.69
Hierarchies	16.45	4.78	13.71	5.62
Cross-links	6.84	12.76	9.35	13.14
Examples	1.26	3.45	.00	.00
Total score	49.29	17.73	37.74	20.18

The following Analyses of Variance (ANOVAs) made it evident that academic achievement had significant effects on constructing propositions, hierarchies, and examples, $Fs(1, 67) = .31.03$, 4.48, and 4.15, ps $< .05$, respectively. Therefore, high-achievers constructed better concept maps than did low-achievers in all the three aspects.

Creativity and Concept Mapping

A canonical correlation analysis was performed to investigate the relationships among the indices of creativity (fluency, flexibility, and originality) and those of concept mapping (constructing propositions, hierarchies, cross-links, and examples). The analysis analyses yielded a significant canonical correlation, $\Lambda = .50$, $p < .001$ (see Table 4). The canonical correlation was .64, representing a 41% overlapping variance for the pair

TABLE 4. Summery Table of Canonical Correlation Analysis of Creativity and Concept Mapping.

Variables	**Canonical Variate**		
	Correlations	**Coefficients**	
Creativity			
Fluency	.92	.50	
Flexibility	.99	.76	
Originality	.81	-.26	
Percent of Variance			Total = 82.79
Redundancy			Total = 33.87
Concept Mapping			
Propositions	.96	.98	
Hierarchies	.48	.12	
Cross-links	-.09	-.26	
Examples	.14	-.09	
Percent of Variance			Total = 29.33
Redundancy			Total = 12.00
Canonical Correlation (χ)	.64		
Squared Canonical Correlation (χ^2)	.41		
Wilks' Λ	.50***		

*** $p < .001$.

of canonical variate. The pair of canonical variate had high factor loadings on all the indices of creativity; the factor loadings were .92, .99, and .81 for fluency, flexibility, and originality, respectively. As for concept mapping, the pair of canonical variate had a strikingly high level of factor loading on propositions (.96), a medium level on hierarchies (.48), but a very low level on cross-links and examples (-.09 and .14), indicating that the skills of creativity and the abilities of concept mapping, especially of making propositions and identifying hierarchies, had a strong positive correlation.

Moreover, the canonical variate accounts for 82.8% of the variance in the creativity variate and 29.33% of the variance in the concept mapping variate While the creativity variate can account for 33.87% of the variance in concept mapping through the canonical variate, the concept mapping variate can only account for 12.00% of the variance in creativity through the canonical variate.

Predictive Power of Creativity and Academic Achievement in Determining Group Membership with Respect to Concept Mapping Ability

A discriminant analysis was also employed to explore the predictive power of creativity along with academic achievement when identifying group membership based on concept mapping ability. The concept mapping ability was grouped into three groups and the two cutoff scores were M plus and minus (.7) SD; (.7) SD is close to 27% of a sample and is normally used as a cut point. Two sets of discriminant functions were extracted, but only one set was significant, $\Lambda = .75$, $\chi^2\,(df = 8) = 18.22$, $p < .01$. That is, students' abilities in fluency, flexibility, and originality as well as academic achievement could significantly predict their memberships in groups as categorized by concept mapping ability.

As concerns relative contributions, "fluency" and "academic achievement" had the highest predictive power (both structural loadings were .88); nevertheless, the other two variables still had a high level of predictive power (structural loadings were .82 for flexibility and .73 for originality). With respect to the classification results, 50.7% of those originally grouped had been correctly classified (see Table 5). More precisely, 78.9% of the students had been correctly classified into the predicted low-ability group, 41.4% into the predicted median-ability group, and 37.5% into the predicted high-ability group in concept mapping. Therefore, creativity and academic achievement can moderately predict the seventh graders' group membership regarding their ability to make a cross-domain concept map.

TABLE 5. Frequency and Percentage of Correct Classification.

	Group	Predicted Group Membership			Total
		Low	Median	High	
Original Count (%)	Low	15(78.9)	3(15.8)	1 (5.3)	19(100.0)
	Median	11(32.4)	16(41.4)	9(26.5)	34(100.0)
	High	4(25.0)	6(37.5)	6(37.5)	16(100.0)

Note. 50.7% of the individuals originally grouped had been correctly classified.

DISCUSSION

Academic Achievement, Creativity, and Cross-domain Concept Mapping

While the first two hypotheses proposed in this study were strongly supported, the third one was moderately supported. More specifically, the findings in this study reveal that (a) high-achievers construct better concept maps than do low-achievers; (b) the abilities of creative thinking as well as those of concept mapping, especially in making propositions and forming hierarchies, are significantly correlated; and (c) academic achievement and creativity, though they can significantly predict the group membership of concept mapping ability, are not as powerful predictors as expected. With a sample size of 69, these findings require further verification.

The findings that the high-achievers made better cross-domain concept maps than did the low-achievers are consistent with those in domain-specific concept mapping studies (e.g. Lian, 1998; Pomson & Hoz, 1998) in three aspects. First, high-achievers are actively engaged in knowledge processing during concept mapping and, seemingly, they use more organizational and elaboration strategies to help them organize concepts in better hierarchical order (Lian, 1998). Second, high-achievers, as might be expected, have better prior knowledge than do low-achievers and this prior knowledge does affect the choices they make as far as the data learners use and the maps they construct (Pomson & Hoz, 1998; Roth & Roychoudhury, 1992; Wallace & Mintzes, 1990; Wandersee, 1990; Wilson, 1996). Third, the ability to construct a concept map illustrates two essential properties of understanding: the presentation and the organization of ideas (Kinchin et al., 2000). Consequently, it is most reasonable to postulate that cross-domain concept maps are useful tools that help teachers understand how their students structure knowledge.

Noteworthy too is that the findings here also confirm the interactive model proposed in this study (see Figure 1) in which I suggested that high-achievers are different from low-achievers in that the former are more active in seeking patterns of information, more effective in detecting patterns and organizing information into schematic patterns, and therefore, have by now constructed richer, more organized schemata. Students do not come to understand a subject by plugging in bits of information. Instead, they are more apt to understand a subject by means of perceiving patterns and relationships. The brain is designed as a pattern detector; it seeks patterns in nature as it is organizing raw data into schemata (Caine & Caine, 1994). Moreover, the brain is continuously evolving and it is a dynamic spatial architect. The function of educators, therefore, must be one of providing students with the sorts of experiences that enable them to perceive "patterns that interconnect." Indeed, students' need to be provided with mental tools to perceive patterns of information and concept mapping is one of these. Besides this, concept mapping is a mechanism that can help teachers understand their students' thinking patterns, which in turn can help instructors reinforce those patterns by providing students with appropriate scaffoldings.

Traditionally, concept mapping has been defined as a process by which learners represent their understanding of the relationships among key ideas in "a domain" of knowledge in graphic form (e.g., Anderson-Inman & Horney, 1997; Adersoon-Inman & Zeitz, 1993). Such a "domain-specific" usage may actually be contradictory to advocating interdisciplinary and integrated learning. This study, therefore, used "cross-domain" concept mapping, under the assumption it would give students more flexibility to integrate knowledge across domains. This assumption has been supported by the significant correlations between the abilities of creative thinking and concept mapping. Well worth noting is that this finding implies that those who can think flexibly and gain new insights should be able to go well beyond textbook information and arrange complex information into different graphic forms, and therefore, construct better cross-domain concept maps. According to the *Cognitive Approach of Creativity* (Ward et al., 1999), the creative process involves an analogical transfer of information from one domain to another. The findings in this study suggest that such a creative process contributes to the construction of a cross-domain concept map.

While creativity may influence the quality of concept maps, concept maps can, in a similar vein, influence creative thinking. As Hyerle (1996) has suggested, by using visual tools that correspond to thinking processes, students can organize their ideas on paper, and as a result, become better thinkers. To add support to this, Ward et al (1999) have reported that accessing knowledge at very abstract levels does contribute to a greater potential for innovation. They claim that all humans have the capacity to generate original or ingenious products and that people tend to project themselves into different roles using metaphors and analogies, starting with a vision and working backward. Concept mapping profoundly affects students' short-term work and long-term thinking abilities (Hyerle, 2000). Further studies may verify whether the use of cross-domain concept mapping can effectively improve students' knowledge and their creativity.

As for the interrelationships among the three main variables used in this study, both the findings of MANOVA and Canonical Correlation Analysis suggest that the abilities of academic learning and creative thinking greatly overlap with those of concept mapping, as evidenced by the high level of variance shared. The significant predictability of academic achievement and creativity on the ability group of concept mapping found in discriminate analysis also supports their interrelationships. These findings tend to support the assumptions made in the interactive model proposed in this study, suggesting that the brain functions by seeking patterns, detecting patterns, and organizing information into schematic patterns underlying the development of cross-domain concept mapping, academic-learning, and creative thinking.

Based on the brain function model, an attitude geared toward actively seeking patterns must be a key factor which brings about all learning outcomes. How one's mind responds to stimuli is guided by general habits of the mind (Hyerle, 2000). Fostering students' habits of actively seeking patterns may improve students' use of strategies and construction of knowledge, which further improves their learning abilities, creative thinking, concept mapping, and finally leads to the improvement of their learning outcome. Since educators are greatly responsible for habituating students to thinking in patterns, they need to develop students' habits of the mind and can do so in numerous ways (Hyerle, 2000): (a) teaching the science of art; (b) teaching the art of science; (c) developing students' senses — especially learning how to see; and (d) making students realize that everything is connected to everything else.

The Development of Concept Mapping Abilities

In this study, students' ability in concept mapping was defined by their competencies in making propositions, hierarchies, cross-links, and examples related to "school violence." On average, the students made about 20 propositions ($M = 20.22$. $SD = 8.96$), 3 hierarchies ($M = 15.22$. $SD = 5.32$), less than one cross-link ($M = 7.97$. $SD = 12.90$) and less than one example ($M = .70$. $SD = 2.62$). Such low cross-linking and example creation scores reveal that on average the students lacked the awareness or ability to integrate concepts and to make connections between abstract ideas and life experiences. Sometimes when students do not use certain strategies, it is not because they do not own the capabilities but because they are not conscious about when or how to use those strategies. Therefore teachers need to identify whether it is a problem of "awareness" or "ability." In either case the emphasis on interdisciplinary instruction should be helpful. This type of instruction stresses nurturing different perspectives with the focus placed on themes and issues related to life experiences (Jacobs, 1989) and therefore helps in improving the learning of higher-order thinking (Arnold & Schell, 1999). Therefore, "cross-domain" concept mapping which fosters the ability to integrate cross-domain knowledge can be an effective tool while implementing interdisciplinary instruction.

Of interest in this study is that no gender differences were found in either the total scores or the sub-skill scores of concept mapping, suggesting that the male and female seventh graders were not developmentally different at visualizing mental concepts. Moreover, incorporating mnemonics as a means to help students understand the steps involved in making a concept map, this study has demonstrated that the seventh graders could learn how to successfully complete the task in a short period of time. In addition, this study employed "student-created maps," in an attempt to motivate students to construct their own concept maps. From observation, the researcher noted that the students were greatly inspired by and attentive in the learning process, which is indicative of the students' learning involvement. This observation confirms Anderson-Inman and Zeitz's (1993) claim that student-created maps encourage student involvement.

CONCLUSIONS

The traditional cognitive model of learning, which emphasizes remembering "bits" of information, has been increasingly challenged for many years. In this new era marked by an explosion of knowledge, educators are responsible for empowering students with the ability to consciously and creatively construct conceptual understandings that link the "bits" into patterns of information. On the basis of the implications from brain function and neurological research, teaching must take a holistic approach to help students "build concepts" and "create the big picture." While educators are continually emphasizing the importance of creative thinking, interdisciplinary learning, and knowledge integration, cross-domain concept mapping should not be overlooked because it encourages the use of complex themes and requires the linking of understanding across various domains. Its importance as a mental tool for understanding student creativity and academic learning has been confirmed by this study.

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