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USING CONCEPT MAPS TRANSCRIBED FROM INTERVIEWS TO QUANTIFY THE STRUCTURE OF PRESCHOOL CHILDREN'S KNOWLEDGE ABOUT PLANTS

Stephanie Wehry[1], James Algina[2], Janice Hunter[1], & Heather Monroe-Ossi[1]
[1]Florida Institute of Education at the University of North Florida, Jacksonville, Florida, USA
[2]University of Florida, Gainesville, Florida, USA
Email; swehry@unf.edu

Abstract. This paper reports the results of an investigation into the usefulness of concept maps to evaluate the structure of preschool children's knowledge about plants. The children, mostly low-SES African-American children, experienced an inquiry-based hands-on science curriculum, the *Young Florida Naturalists*. As part of the evaluation, researchers interviewed the children to ascertain their knowledge about plants. The children's responses were transcribed and used to form concept maps. The researchers developed a scoring system for the concept maps, determined a measure of interrater reliability, and investigated relationships between concept map scores and fall and spring measures of the children's achievement. The estimated interrater reliability for scoring the maps was .98. When the prekindergarten class, gender, and age are controlled, no relationship was found between the children's initial status on measures of school readiness and early literacy achievement and their ability to express complexity in the structure of their knowledge about plants. However, a relationship was found between the children's spring scores on the BBCS-3:R Self-/Social Awareness and Texture/Material scales and their concept map scores.

1 Introduction

Concept mapping has been widely used to assess the structure of children's knowledge especially in science. However, concept mapping is used across many subject domains and across a considerable age span of learners. The purpose of this study was to investigate the reliability and validity of the use of concept maps to assess the concept development of preschool children participating in the *Young Florida Naturalists* project. The project was implemented during the 2006-2007 academic year at an urban, professional learning demonstration preschool center that primarily serves low-SES, African American children. The curriculum was implemented in two classes of 4-year-old prekindergarteners and one class of 3-year-old preschoolers. One or two of the project researchers were on site most of the time during the project's implementation.

Novak and Cañas (2006) stated that a concept map is a graphical tool for representing knowledge. Concept maps include concepts shown by ovals in our study, by the relationship between concepts shown by a linking line with a directional arrow, and by words on the linking lines representing the relationship between the linked concepts. Two linked concepts are called a proposition, and propositions form meaningful statements when read. Concept maps generally represent concepts in a hierarchical fashion with the most general concepts at the top. Concept maps can also have cross-links which connect concepts in different segments (branches, domains, or strings) of the map. Novak and Cañas contended that the two features of concept maps that indicate *leaps of creative thinking* are the hierarchal structure of the map and the use of cross-links.

Novak and Cañas (2006) also advocated concrete experiences and hands-on learning with young children.

> After age 3, new concept and propositional learning is mediated heavily by language, and takes place primarily by a *reception learning* process where new meanings are obtained by asking questions and getting clarification of relationships between old concepts and propositions and new concepts and propositions. This acquisition is mediated in a very important way when concrete experiences or props are available; hence the importance of "hands-on" activity for science learning with young children, but this is also true with learners of any age and in any subject matter domain. (page 3)

The *Young Florida Naturalists* project was based on the same tenets posited by Novak and Cañas and focused on three goals to increase the background knowledge and concept development of preschool children. The first goal was to increase young children's knowledge of plants and their role in the environment. The second was to introduce scientific learning through hands-on instructional experiences. The third was to examine the utility of concept mapping as a tool to track concept development in young preschool children.

2 The Intervention: *Young Florida Naturalists*

The *Young Florida Naturalists* project builds on the work of Hirsch (2006), Neuman and Celano (2006), Novak and Gowin (1984), and Zimmerman (2005) regarding concept mapping, elementary science learning, and the knowledge gap of at-risk, young children. Learning experiences involved plants and their role in the environment. Instructional activities included advance organizers to guide the children's investigations which included activities that demonstrate the effects of water, sunlight, air and soil on plant growth. Building background knowledge was emphasized as the children engaged in concrete experiences with plants in a butterfly garden developed on the center's grounds. Vocabulary development was emphasized through read aloud activities based on environmental books. Concept mapping was used to document the hierarchical relationships described by the children before, during, and after learning experiences had been initiated.

2.1 Assessment and Scoring of Young Florida Naturalists Project Concept Maps

One formative assessment of the children's achievement consisted of an individual interview which began with the question—*What do we know about plants?* Children were assessed individually by research staff and their responses were transcribed. Concept maps were constructed to reflect their statements about plants.

Ruiz-Prima and Shavelson (1996) developed a framework for using concept maps for assessment in science. The framework describes concept map production as the interrelationship of three facets of the map: task for the child, format of the response, and a scoring system that produces accurate and consistent results. The evaluation of the concept maps in this study builds on their framework. Moreover, we assumed the concept maps would be hierarchical in structure and describe the children's classification and sorting systems; however, Hall, Dansereau, and Skaggs (1992) suggested that the structure of concept maps actually depends on the nature of the knowledge being mapped. Safayeni, Derbentseva, and Cañas (2005) suggested that different structures of maps make useful distinctions between process and content. The relationships between concepts can be static or dynamic with static relationships serving to define, describe, and organize knowledge and dynamic statements serving to describe processes.

The task format our children experienced was low-directed. Ruiz-Prima, Schultz, Li, and Shavelson (2001) found that high- and low-directed maps provide different information about the structure of the student's connected knowledge, and that low-directed maps better reflect the students' knowledge structures. However, our children's task was not completely low-directed as the interview protocol provided some structure. The structured interview, conducted May 2-3, 2007, began with the researcher saying to the child; *Tell me what you know about plants*. During the interview, the researchers also used these prompts: *What makes you say that*, *Tell me more about…*, *What else have you learned about…*, *Do you have anything else to add about…*, *Can you think of something else to add?* and redirecting with *We want to know what you know about plants*. The children were not provided links, and their responses were not constrained by any structure other than the interview protocol.

The format for the children's response was oral explanation. A researcher, knowledgeable about the curriculum but with no direct contact with the children, transformed the children's responses into concept maps. Thus, the mapper relied only on the children's responses to form the concept maps. Figure 1 provides examples showing two of the children's oral and mapped responses. The concept map on the left shows connected, unconnected, and partially correct knowledge. The concept map has no cross-links, but does have two levels beyond the focal concept. The concept map on the right is simpler and introduces irrelevant knowledge.

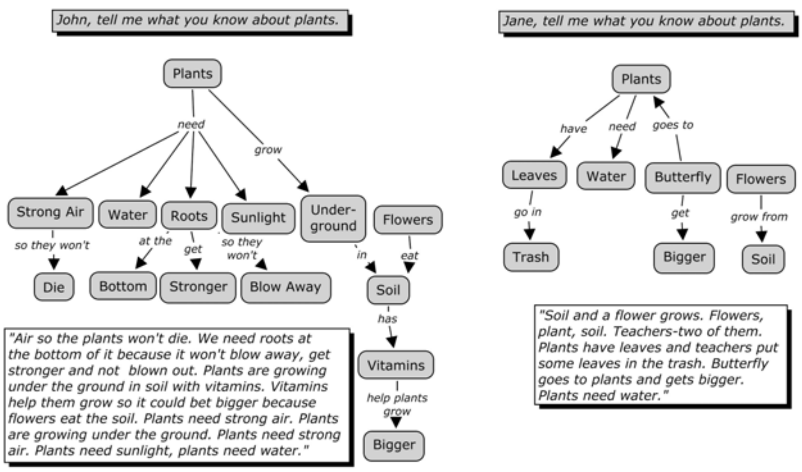

Figure 1. Two examples the children's responses to the interview focal question and the corresponding concept maps.

We expected most of the concept maps would indicate attributes as suggested in the two examples provided in Figure 1. However, because the children had observed and conducted several experiments as part of the inquiry-based curriculum their responses were influenced by these experiences, and they described processes as well as content. For example, the children observed various colors added to water containing white carnations and learned that *stems suck up water like a straw* and that the flower changes color (a dynamic statement). The children also planted seeds in styrofoam cups and watched them become plants, and they sometimes described the planting process in their responses. Furthermore, prior to this assessment, the children planted a butterfly garden and watched the butterfly metamorphous during the school year. Their responses frequently included irrelevant and not fully connected concepts from the butterfly garden and other hands-on experiences. The use of dynamic and somewhat irrelevant but true propositions presented mapping challenges.

3 Scoring the Children's Concept Maps

The scoring system used to assess the concepts maps was an adaptation of a system developed by Novak and Gowin (1984). The quality of the propositions were scored in a manner similar to that proposed by Kinchin (2000), McClure and Bell (1990), and Yin, Vanides, Ruiz-Prima, Ayala, and Shavelson (2005). The system provides scores for three components of the map: propositions, cross-links, and hierarchy.

3.1 The Scoring System

The concept map score is the sum of the scores for the three components. First, the propositions are scored. Propositions receive 0 points if the proposition is incorrect or is totally irrelevant, 1 point if the proposition is correct but is somewhat relevant or if the proposition provides an example of the concept (e.g., flowers can be pink), 2 points if the proposition describes an attribute of the concept, and 3 points if the proposition states a purpose of the attribute. Propositions receiving 2 or 3 points are considered quality propositions. Second, cross-links are scored. Cross-links connect concepts in different strings (branches or segments) of the concept map and receive 5 points. Cross-links connect concepts at different or at the same levels in the map's hierarchy but to receive points they must link concepts that are part of a quality propositions. Each sufficient cross-link receives 5 points and receives no proposition points. Figure 2 provides examples of cross-links that are sufficient and insufficient. The focal concept in each example is *plants*. Numbers in parentheses represent the points awarded for the propositions or cross-links.

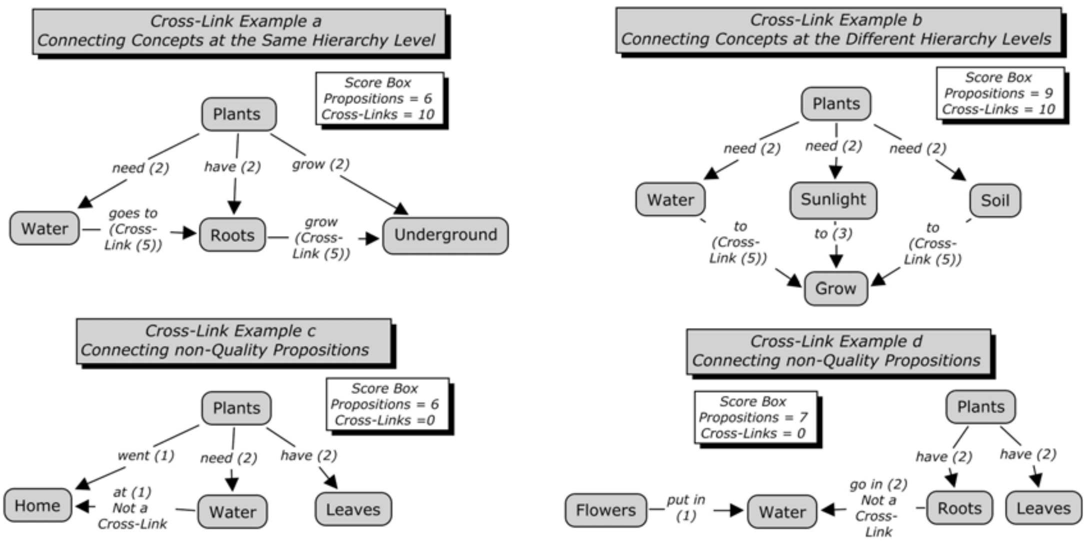

Figure 2. Examples of cross-links sufficient or insufficient to receive points.

Example a shows three quality propositions and two sufficient cross-links. Each cross-link receives 5 points. *Example b* shows three quality propositions involving the focal concept, *plants*. These three concepts all connect to a fourth concept, *grow*. One of the resulting three connections receives 3 points because it is in the same branch of the map and describes a purpose of the concept, *sunlight*. The other two connections are sufficient cross-links and each receives 5 points. *Example c* shows a proposition connecting *home* with the focal concept, *plants*, that receives 1 point because it is true but somewhat irrelevant and a proposition connecting *home* to *water*. This cross-link is insufficient to receive points because *home* is not connected to *plants* with a quality proposition. *Example d* shows a proposition between *flowers* and *water* that receives 1 point as it is somewhat irrelevant (it also does not include the focal concept); therefore, *water* cannot form a cross-link that is sufficient to receive points. However, the r*oots-water* proposition is a quality proposition and receives 2 points.

Last, hierarchy levels are scored. Level one, the focal concept, receives no points. A scored level two is established when three or more concepts form quality propositions with the focal concept. A specified number of branches was chosen to avoid rewarding string maps with hierarchy points. Level two receives 5 points. Examples of level two are presented in the Figure 3.

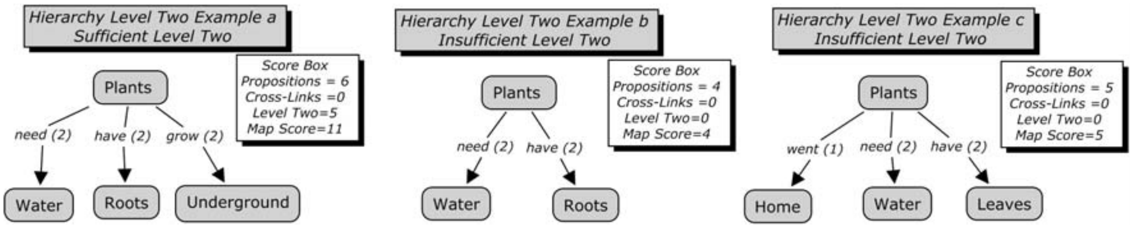

Figure 3. Examples of hierarchy level two concepts sufficient or insufficient to receive points.

Example a shows three concepts, *water*, *roots*, and *underground*, connected with quality propositions to the focal concept. This example of hierarchy level two is sufficient to receive 5 points. *Example b* shows only two quality propositions with the focal concept; therefore, this level two is insufficient to receive 5 points. *Example c* shows only two quality propositions with the focal concept; therefore, the level two is insufficient to receive 5 points.

A scored level three is established when new concepts are connected with quality propositions or scored cross-links to three or more level two concepts involved in quality propositions with the focal concept. Examples of level three are presented in the Figure 4.

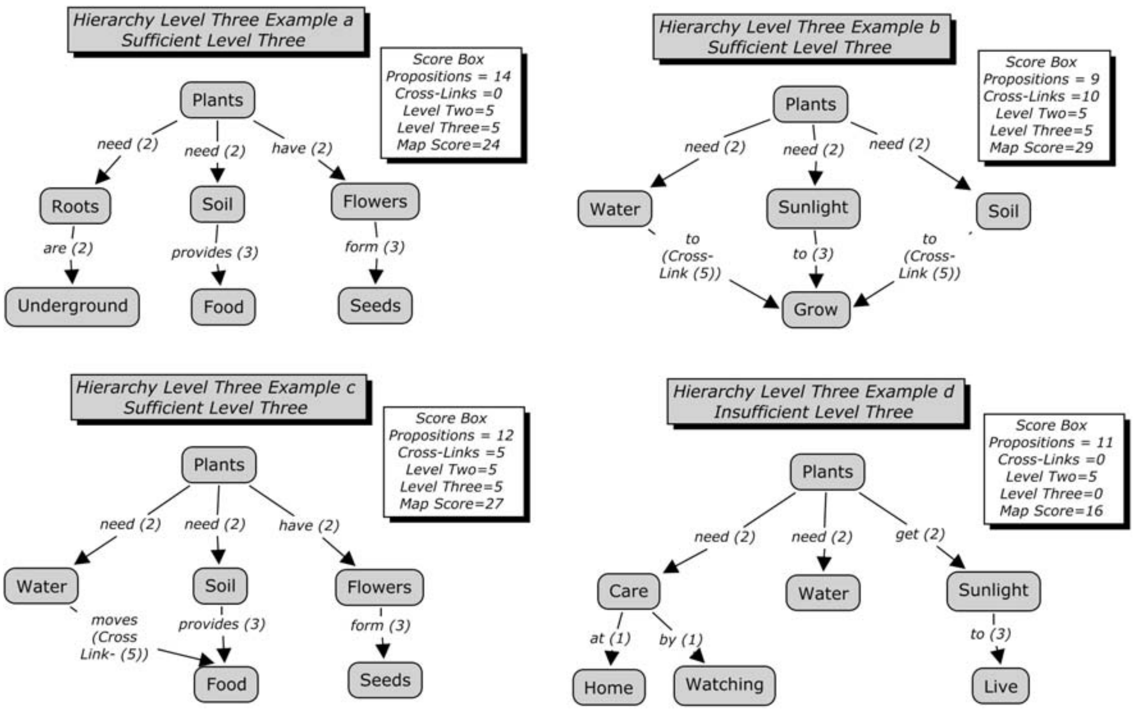

Figure 4. Examples of hierarchy level three concepts sufficient or insufficient to receive points.

Example a shows three level two concepts that form quality propositions with the focal concept (5 points awarded for level two) and each level two concept is involved in a quality proposition with a level three concept. This is sufficient for awarding 5 points for level three. *Example b* shows three level two concepts that form quality propositions with the focal concept (5 points awarded for level two) and all level two concepts are involved in quality propositions or scored cross-links with a single level three concept, *grow*. Because there are three scored quality connections, this is an example of a level three that is sufficient to receive 5 points. *Example c* shows three level two concepts that form quality propositions with the focal concept (5 points awarded for level two) and that have three quality connections (two quality propositions and one scored cross-link) with two level three concepts. Because there are three quality connections, this is an example of a level three that is sufficient to receive 5 points. *Example d* shows three level two concepts that form quality propositions with the focal concept (5 points awarded for level two); however, two of the three connections with level three concepts are propositions receiving 1 point and are, therefore, not of quality. This is an example of a level three that is insufficient to receive 5 points.

4 Results

4.1 Interrater Reliability

Training in the use of the scoring system was provided to three researchers who then independently scored 48 concepts maps constructed from the transcribed interviews of children in two prekindergarten classes and one preschool class of 3 year olds. To examine the generalizibility of scores across raters, four map (p) by rater (r) G studies were conducted for three components of the concept map score and the total score. The results of the G studies are presented in Table 1.

The G studies indicated the interrater reliability is .96, .90, .94, and .98 for the propositions, cross-link, hierarchy, and total score, respectively. Raters contributed little to the total variance of the concept map scores. The researchers' concept map scores were averaged across raters and the resulting concept map score was used in the remaining analyses

	Concept Map Score Types							
	Proposition Score		Cross-Link Scores		Hierarchy Score		Total Score	
Source of Variation	Estimated Variance Component	Percent of Total Variability	Estimated Variance Component	Percent of Total Variability	Estimated Variance Component	Percent of Total Variability	Estimated Variance Component	Percent of Total Variability
Maps (p)	40.56	86.15	23.81	70.84	14.20	82.79	200.24	94.53
Raters (r)	0.95	2.01	1.55	4.61	0.22	1.27	0.10	0.05
pr,e	5.57	11.84	8.25	24.54	2.73	15.95	11.50	5.43
$\hat{\rho}^2$ relative	.96		.90		.94		.98	
$\hat{\phi}$ absolute	.95		.88		.94		.98	

Table 1: Generalizibility Study Results

4.2 Concept Map Scores Differences by Population Subclasses

Ethnicity, gender, and date of birth information were available for 30 of the prekindergarteners. Date of birth was used to calculate the children's age in months on September 1, 2006. All but one child was African American, 53% were boys, and 57% were no more than 54 months old on September 1. The gender and age variables were tested in a regression that controlled for class. Results of the regression are presented in Table 2.

Source of Variance	*df*	Mean Square	F ratio	*p*-value
Class	1	714.24	4.13	.0530
Gender	1	643.96	3.72	.0622
Age	1	244.52	1.41	.2457
Class*Age	1	785.16	4.54	.0432

Table 2: Regression Results

The children's concept map scores were differentiated by gender and there was a statistically significant class by age interaction. The adjusted mean score for girls was 27.48 and for boys was 18.17 indicating that the structure of the girls' knowledge represented on the concept maps was more complex than the boys. In one class, older children had higher concept map scores and, in the other class, age did not predict the children's scores.

4.3 Correlations of Concept Map and Achievement Scores

Prekindergarteners participating in the *Young Florida Naturalists* project were assessed as part of the evaluation of a community initiative which provided support to preschool centers serving low-income neighborhoods. The evaluation consisted of fall and spring assessments of the children using the Test of Early Reading Ability-Third Edition (TERA-3; Reid, Hresko, & Hammil, 2001) and the Bracken Concept Scale-Third Edition: Receptive (BBCS-3:R; Bracken, 2006). TERA-3 assesses components of early reading skills, including familiarity with the letters of the alphabet and numerals, discovery of the arbitrary conventions used in reading and writing English, and recognition that print conveys information, ideas, and thoughts. TERA-3 is composed of three scales: Alphabet, Conventions, and Meaning, each measuring one of the three components. Coefficient alphas for the TERA-3 when used with children between 4 and 5 years old range from .82 to .95. The BBCS-3:R is a receptive measure of children's basic concept development and includes ten scales: Colors, Letters, Numbers/Counting, Sizes/Comparisons, Shapes, Direction/Position, Self-/Social Awareness, Texture/Material, Quantity, and Time/Sequence. The first five scales form the School Readiness Composite (SRC). Internal consistency coefficients for the BBCS-3:R when used with children between 3 and 5 years old range from .94 to .98.

The concept map scores of the prekindergarteners were used in conjunction with the available fall and spring TERA-3 and BBCS-3:R scores to investigate associations between concept map and achievement scores. Children's raw achievement scores were used as concept map scores were not standardized. The interest was in achievement scores relative to the children in the *Young Florida Naturalists* classes. Table 3 shows the estimated correlations between the children's concept map and achievement scores.

Test	Subtest	Fall			Spring		
		Mean	Correlation	*p*-value	Mean	Correlation	*p*-value
TERA-3	Alphabet	10.47	.14	.49	12.07	**.42**	**.03**
	Conventions	8.37	.08	.71	9.14	.27	.19
	Meaning	5.37	**.39**	**.04**	7.72	.21	.30
BBCS-3:R	SRC	45.48	.12	.56	62.00	**.36**	**.07**
	Direction/Position	25.55	.13	.52	37.79	.30	.14
	Self-/Social Awareness	22.21	.19	.36	27.29	**.40**	**.05**
	Texture/Material	12.59	.01	.97	15.86	**.36**	**.08**
	Quantity	15.21	.25	.21	19.57	.17	.40
	Time/Sequence	10.69	.05	.81	16.82	.12	.56

Note: In the fall, 27 children had both TERA-3 and concept map scores and 26 had both BBCS-3:R and concept map scores. In the spring, 26 children had both TERA-3 and concept map scores and 25 had both BBCS-3:R and concept map scores.

Table 3: Correlations of Achievement Test Means and Concept Map Scores

Bold-faced correlations were statistically significant at alpha=.10. Four of these five correlations were with spring achievement scores. Because gender and an interaction between class and age predicted the children's concept map scores, we wanted to control for these variables in studying the relationship between the spring achievement and concept map scores. A regression was conducted for each spring variable significantly correlated with concept map scores. For the one fall achievement score, we wanted to know if fall achievement predicted the concept map score over and above class, gender, age, and a class by age interaction. Results of the analyses are reported in Table 4.

Bold-faced *p*-values indicate the concept map scores were statistically significant (alpha=.05) predictors of the achievement measured by the BBCS-3:R Texture/Materials and Self-/Social Awareness scales. The Self-/Social Awareness scale assesses person-oriented knowledge. Inspection of the scale items shows that children were asked to select pictures that correspond to named attributes of people and/or relationships among people. The Texture/Material scale assesses children's knowledge about the attributes of objects in their environment. Children learn of these attributes by using their sight, touch, and hearing to identify, name, and discriminate between various object attributes, characteristics, and qualities. These two findings are particularly rewarding as associations with these measures correspond with the quality propositions that are the building blocks used to quantify concept map structure.

Model	Time	Source of Variance	F-Ratio	*p*-value
CMap Score on TERA-3 Meaning	Fall	Class	2.97	.0987
		Age	0.13	.7207
		Class*Age	2.72	.0890
		TERA-3 Meaning	2.33	.1411
TERA-3 Alphabet on CMap Score	Spring	Class	4.13	.0543
		Gender	4.91	.0373
		CMap Score	0.94	.3422
BBCS-3:R School Readiness Composite on CMap Score	Spring	Gender	3.93	.0600
		CMap Score	1.41	.2474
BBCS-3:R Texture/Materials on CMap Score	Spring	Class	3.03	.0954
		CMap Score	4.92	**.0371**
BBCS-3:R Self-/Social Awareness on CMap Score	Spring	Class	7.33	.0132
		Age	3.20	.0881
		CMap Score	6.61	**.0178**

Table 4: Achievement Score Regression Results

5 Conclusions

This small study indicated that it is possible to quantify the structure of preschool children's concept maps constructed from interviews. Concept maps can be scored reliably by university researchers, and the complexity of the maps predicted children's achievement scores measuring the development of person-oriented knowledge and knowledge about the attributes of common objects in their environment. However, there are limitations to these findings. Specifically, the results cannot be generalized beyond the *Young Florida Naturalists* curriculum and the three preschool classes at this one center. Additionally, at this point, the formation and scoring of the concept maps cannot be generalized beyond university researchers to practitioners in preschool settings. The results are further confounded by the age and low-SES status of the children. According to Novak and Cañas (2006), language and concrete experiences mediate propositional learning. The children's interview responses are only as good as their ability to use language to communicate their knowledge. This study did not investigate the relationship between the children's language development and the complexity of their concept maps.

5.1 Implication for Practice

Novak and Musonda (1991), in a study that constructed concept maps from young children's transcribed interviews, found that rating the interviews did not provide clarity when determining the structure of the children's knowledge relative to the entire domain. However, construction of concept maps allowed the respondent's propositions to be arranged in a hierarchical form and cross-links illustrated. Our experiences with preschool children's concept maps similarly showed that their maps could be useful as formative assessments. We suggest that concept maps can and should be used to assess children's knowledge structure during the implementation of the curriculum. For example, the two concept maps shown in Figure 1 provide examples of children's propositions that show areas where teachers could clarify the children's knowledge structures. Neither John nor Jane could connect *flowers* with the focal concept, *plants*. It is not clear whether they viewed *flowers* as a synonym for *plants* as suggested in everyday language such as "Let's plant some flowers along the border of the walk," whether John and Jane viewed *flowers* as an attribute of plants, or whether they viewed flowers as something entirely different. John's map also presents a dilemma to the raters with the proposition *flowers eat soil*. The map rater must determine whether John uses *eat* generically to mean *takes in food* or whether John means a more literal use of *eat*. Jane's knowledge is much more fragmented and is tied closely to classroom experiences with plants. These examples of knowledge structures derived from the children's maps could be helpful in clarifying children's knowledge as well as to refining the curriculum before further implementation.

5.1 Further Research

Several avenues for future research are evident from this study. First, the concept maps in this study were constructed by one researcher. A mapping protocol for constructing concept maps from the children's transcribed interviews needs to be developed and tested for intermapper reliability. Second, both the scoring system and mapping protocol need to be adapted for use by practitioners. The relationship between the practitioner and the researcher's concept map scores should be investigated. Finally, a purpose of the *Young Florida Naturalists* project was to enhance the vocabulary development of the preschool children. The TERA-3 and BBCS-3:R assess important school readiness skills, but do not directly assess vocabulary. An investigation of the association between the scores of concept map and vocabulary measures such as the Peabody Picture Vocabulary Test-Fourth Edition (PPVT-4; Dunn & Dunn, 2007) should be conducted.

6 Acknowledgment

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