The Process of Collaborative Concept Mapping in Kindergarten and the Effect on Critical Thinking Skills

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Abstract

To develop and nurture critical thinking, students must have opportunities to observe and practice critical thinking in the classroom. In this parallel mixed method classroom study, we investigate the role of collaborative concept mapping in the development of kindergarten learners' critical thinking skills of analysis and interpretation over a five week period. Learners had two large group experiences and three dyad experiences of collaborative concept mapping. Results showed significant increases in critical thinking skills in the five week period when learners engaged in collaborative concept mapping supported by mentorship, discussion, and real-life scenarios. We propose collaborative concept mapping as an instructional strategy to develop critical thinking skills in the kindergarten classroom. Implications for future research and practice are discussed.

Keywords: Critical thinking, concept map, kindergarten, collaborative, mixed method

Critical thinking enables learners to make sound and logical decisions and engage in meaningful learning (Facione, 2010; Helsdingen, Van Gog, & Van Merriënboer, 2011). Researchers have characterized critical thinking as a combination of higher order cognitive skills and dispositions (Ennis, 1987; Facione, 1990; Glaser, 1941; Lipman, 1991; Paul, 1990; Siegel, 1988), with the acknowledgement that critical thinking underlies judicious debate. To develop and nurture critical thinking, students must have opportunities to observe and practice critical thinking in the classroom (ten Dam & Volman, 2004). In this study, we focus on the critical thinking skills of analysis and interpretation. Analysis is the skill of identifying intended and actual inferential relationships among forms of representation intended to express meaning and consists of sub skills such as examining ideas and identifying arguments, reasons, and claims (Facione, 2010). For instance, a child exclaiming that they got wet *because* of the rain demonstrates their ability to analyze the situation. When the child evidences their similarity to others who are wet because of the rain, they exhibit the critical thinking skill of interpretation. Interpretation is the skill of comprehending and expressing meaning or significance of presented information (Facione, 2010). Interpretation consists of sub skills such as categorization, decoding significance, and clarifying meaning (Facione, 2010). Analysis and interpretation have been incorporated, in part, into the Common Core State Standards for math content by requiring kindergarten learners to compare objects and describe the difference (standard K.M.D.A.2) as well as classify objects into given categories (standard K.M.D.B.3). Thus, in this study we seek to integrate math skills and science content, motivated by the need for more research on integrating STEM instruction highlighted by several researchers (e.g., Becker & Park, 2011; Moore & Smith, 2014) in elementary curriculum through an interactive and constructive activity (i.e. concept mapping) led by a teacher (Katehi, Pearson, & Feder, 2009).

Concept mapping is the process of creating concept maps that are graphical tools for organizing and representing knowledge through a set of propositions (Novak & Cañas, 2008). Abel and Freeze (2006) evaluated concept mapping as an activity that reflects critical thinking by promoting identification of nonlinear relationships among the components of a process. They concluded that early introduction to concept mapping is advantageous to increasing learners' critical-thinking ability over time (Abel & Freeze, 2006). Although numerous studies with adult learners have investigated concept mapping as an instructional strategy to increase learning and critical thinking outcomes (Authors, 2006; Cheng, Liang, Lee, & Liao, 2011; Lee, Chiang, Liao, Lee, Chen, & Liang, 2013; Maneval, Filburn, Deringer, & Lum, 2011), little is known about the role of concept mapping in developing young learners' critical thinking.

Concept mapping as an instructional strategy for young learners

In a recent systematic review (Authors, 2015), we note that concept maps have been used in a variety of settings including preschool (e.g. Mancinelli, Gentili, Priori & Valitutti, 2004), elementary school classroom (e.g. Mancinelli, 2006) and childcare (e.g. Hunter, Wehry, & McLemore, 2010). Concept maps have been used to assess content knowledge (e.g. Cassata & French, 2006), identify relationships between different concepts (e.g. Mancinelli et al., 2004), and organize knowledge (e.g. Monroe-Ossi, Wehry, Algina, & Hunter; 2008). While most studies we reviewed had young learners constructing concept maps themselves, there were some studies in which children were interviewed and researchers developed the concept map from interview transcripts (e.g. Monroe-Ossi et al., 2008). In this paper, we focus exclusively on young learners constructing their concept maps.

Novak and Wandersee (1990) theorized that young learners may learn how to make "good" concept maps quickly since they have not yet been exposed to extensive rote-learning. Correspondingly, Stice and Alvarez (1987) observed that concept maps provided opportunities for direct instruction and appeared to be developmentally appropriate for young learners with low achievement scores in K-5. For example, Giombini (2004) presented drawings by four and five year olds as the starting point of concept maps explaining that some young learners around the age of 5.5 years were able to write a few words to describe their picture (concepts) and indicate directionality using arrows to view the pictures (read the concepts). Birbili (2006) concluded from her systematic review that if introduced and used in developmentally appropriate ways and supported by teacher scaffolding, young learners could construct concept maps with the acknowledgement that some young learners would not be able to use and understand various ways of representation.

In a previous systematic review, we identified three common ways researchers made concept mapping a developmentally-appropriate activity for kindergarten learners (Authors, 2015). First, young learners constructed concept maps on familiar topics after engaging with concrete objects or real-life experiences. Second, young learners constructed their concept map first in large groups with discussions and then individually. Third, concepts were represented by pictures or photos when young learners constructed their own concept maps and rarely included linking words. These adaptations depart from traditional concept mapping (Novak & Canas, 2006) by (i) not having recorded linking words and (ii) using pictures instead of words to represent concepts. However, Gallenstein (2005) advocates that these

adaptations provide opportunities for young learners to engage in concept mapping and see logical connections between their prior and new knowledge by promoting skills of critical thinking, observation, comparison, and classification. As much as the activity may be adapted, Abrami, Bernard, Borokhovski, Waddington, Wade, and Persson (2015) suggest that mentorship, discussions, and real life scenarios play a critical role in effective critical thinking instruction. Thus, we briefly review the research demonstrating how mentorship, discussions, and real life experiences influenced young learners' concept mapping.

Mentorship. Cassata and French (2006) suggest that scaffolding techniques such as limiting group size, restricting the number of concepts, activating prior knowledge, and modeling metacognitive talk will likely encourage young learners' metacognitive behaviors such as verbalizing questions, selecting concepts, planning concept placement, identifying gaps, and making connections. Cassata-Widera (2008) demonstrated that teacher scaffolding and an increased number of learned concepts supported kindergarten learners to discuss a single concept from different perspectives, represent their knowledge in a construct map, identify new propositions and speak in de-contextualized (expository) language to present and summarize their information. These studies provide preliminary evidence to the role of the teacher, the mentor, in the concept mapping process.

Discussions. Several studies, many a part of the MIUR Pilot Project "Le parole della scienza", considered the role of discussions when young learners concept map, especially after real life experiences. In the MIUR project, 56 kindergarten learners (four to five years old) created 180 concept maps in their notebooks. Learners discussed their experience and observations after exploring an object or experience and construct their ideas or engage in certain experiences prior to creating a group concept map. In a study from this project, Mancinelli (2006) concluded that each child was inclined to discuss and explain their map to a group but preferred to construct individual maps to express their own learning. Mancinelli (2006) also proposed that concept maps provide a common starting point to identify similarities and differences among concepts as well as mediate stimulation, language, and facilitate socialization.

Real life scenarios. In another study as part of the MIUR Pilot Project, Mancinelli, Gentili, Priori, and Valitutti (2004) had young learners create and explore Papier-mâché pumpkins. Learners discussed the parts of a pumpkin before drawing pictures to represent concepts related to the pumpkin. Mancinelli et al. (2004) observed that young learners were able to translate their understanding of the concepts onto a concept map and concluded that these primitive concept maps reflected young learners' extent of understanding of the concepts and the relationships between concepts related to a pumpkin. They also noted that even though some concept maps did not have directionality indicated or linking words, they still have the potential to provide teachers sufficient information to identify misconceptions. Similar findings were observed in studies outside of the MIUR project as well. Aquilino and Venditti (2006) conducted a study in which young learners (aged three to five years) visited and observed a paper factory, created their own paper in the school lab, and then proceeded to concept map as a group before constructing their individual concept map using paper samples, drawings, and linking words. In another study Figueiredo, Lopes, Firmino, and Sousa (2004) found young learners demonstrated meta-cognitive awareness, a core competency relevant to the development of critical thinking (Kuhn, 1999) indicating the potential of higher order thinking in the early classroom. Figueiredo et al. (2004) helped 13 young learners aged three to five years in a preschool setting learn and track their knowledge about the cow using pictures instead of words in a concept map, first as a group and then individually, after a trip to a dairy farm. Figueiredo et al. (2004) found some young learners were able to identify that the concept map helped them to "know what they know" about the cow and other young learners were able to identify various concepts connected to the cow.

Thus, mentorship, discussions, and real life scenarios are identified in dispersed qualitative inquiry of collaborative concept mapping in early childhood. There is insufficient understanding of how mentorship, discussions, and real life scenarios shape the concept mapping process together. Further, there is inadequate quantitative investigation of the effectiveness of repeated concept mapping as an instructional strategy to develop young learners' critical thinking skills. In this study, we aim to expand on what we know and address these gaps by adopting a parallel mixed method (Teddlie & Tashakkori, 2009) design employing both quantitative and qualitative methods to investigate one overarching research question: *What is the role of collaborative concept mapping in the development of kindergarten learners' critical thinking skills of analysis and interpretation in the classroom?*

This guiding research question will be addressed by breaking it down to two component research questions. First, how do kindergarten learners' critical thinking skills of analysis and interpretation change across repeated collaborative concept mapping experiences in the classroom? Second, how do mentorship, discussions, and real life experiences shape collaborative concept mapping in a kindergarten classroom?

Method

Design

We adopted a parallel mixed method design (Teddlie & Tashakkori, 2009) to address the guiding research question and its component research questions. In a parallel mixed method design, both quantitative and qualitative methods are simultaneously employed and given equal weight. In this study, the quantitative (QUAN) strand included a pre-post assessment of learners' analysis and interpretation skills. For the qualitative (QUAL) strand, we adopted a case study approach. Learners had a total of five experiences of collaborative concept mapping. Table 1 summarizes the research design and stage for both quantitative and qualitative strands.

Participants

The present study was conducted in a white, low-income kindergarten classroom in a public elementary school in the Northwest region of the United States. The sample is similar to the school's demographics. Approximately 86% of the learners in the school qualified for free and reduced lunch; 81.9% of the school students identified as white; and 52.4% students were male and the remaining 47.6% female. The class had 15 learners, six boys and nine girls, (*Mean* age = 5. 29 years, *SD* = 0. 58) who participated in both the QUAN and QUAL strands of this study. No participating learner was identified as an English language learner, or had a documented learning disability nor required accommodations. The intervention was carried out as regular classroom activity encouraging all students in the classroom to participate. This study was classified as exempt by the Institutional Review Board for Human Subject Research.

Procedure

All learners completed three worksheets each before and after their concept mapping experience (see Table 1). Learners completed their worksheets spread across three days (one worksheet a day) each time to reduce the possibility of fatigue. The researcher administered worksheet A individually and maintained an audio recording of learner responses. The teacher distributed worksheets B and C to students, displayed the worksheet on the projector screen, and read aloud the instructions for each question. Details about the worksheets are provided in the 'Measures and scoring' section.

Learners had one forty minute experience of collaborative concept mapping every week for five weeks. The first two experiences were large group and the remaining three were in dyads. The large group experiences were class demonstrations led by the teacher during which time learners suggested concepts to include and possible relationships between the concepts on the board. The large group experiences were an opportunity for teachers to model the concept mapping process of identifying concepts to include and explicating relationships between concepts. The large group experiences also allowed the teacher to model collaborative behavior, as well as how to read a concept map.

In the large group experience, the teacher huddled

Week : *Stage*	Procedure	QUANT	QUAL
0: *Data Collection*	Typical classroom instruction targeted content in the concept maps	Scores on worksheet A, B,and C (Pretest)	N/A
1: *Data Collection & Intervention*	1st Large group exposure: Changes in environment with 9 concepts	N/A	Observation field notes Informal instructor interview Video recording
2: *Data Collection & Intervention*	2nd Large group exposure: Weather concept map with 10 concepts	N/A	Video recording Informal instructor interview
3: *Data Collection & Intervention*	1st Dyad Exposure: Weather concept map; same 10 concepts as Week 2	N/A	Observation field notes Informal instructor interview Video recording Dyad concept maps
4: *Data Collection & Intervention*	2nd Dyad Exposure: Weather concept map; same 10 concepts as Week 2 and a short title 'Weather'	N/A	Video recording Informal instructor interview Dyad concept maps
5: *Data Collection & Intervention*	3rd Dyad Exposure: Weather concept map; same 10 concepts as Week 2, title words (When – the – weather – is), and concept pictures of the seasons - fall, winter, summer, and spring	N/A	Audio recording Informal instructor interview Dyad concept maps
6: *Data Collection*	Post-test	Scores on worksheet A, B1,C (Post-test)	N/A
Analyses	N/A	MANCOVA, with age as covariate	Content analysis Narrative analysis
Results	N/A	Statistically significant gain from pre to post	Personalization of concept map construction and interpretation; analysis of relationships
Meta Inference	N/A	Positive role in development of critical thinking skills of analysis and interpretation of kindergarten learners	

Table 1. Research Design Summary

learners near the felt board in class. On one side of the felt board, the teacher had all the concepts and arrows for the concept map. The top of the felt board had the unit title (Changes in the environment for Week 1 and Weather for Week 2). The teacher then led the large group experience where learners collaborated by suggesting which concepts to include and possible relationships between the concepts on the board. The teacher was given autonomy in the execution of the concept mapping process, i.e. no additional instructions were provided. A richer description of how the teacher executed this process is outlined in the 'Mentorship' section.

In the dyad experiences, learners were given packets that include the printed concept pictures, arrows, linking words, and the paper on which learners will create their concept map. To construct their concept map, learners discussed amongst themselves and laid out the pictures in the order they intended to paste them on the sheet. Then the teacher would review the layout and ask questions if they identified any misconception or if a concept was or was not included. After this discussion, learners were given the choice to incorporate feedback before they pasted their pictures and arrows as a concept map. At the end of the class period (40 minutes), learners submitted their concept maps to the teacher. These dyad experiences gave learners the opportunity to practice collaborative concept mapping.

In the first dyad experience, learners had access to the ten concepts and arrows used in class. They were not given a title or printed linking words. In the second dyad experience, learners were provided a short printed title ('Weather'), and in the last dyad experience a longer title broken into four words (When – the – weather – is) as well as four additional concept pictures of the seasons - fall, winter, summer, and spring were included as concept mapping material. These increments were suggested by the teacher to avoid activity fatigue. From a research perspective, it allowed us to review whether kindergarten learners were able to accommodate new pieces of information in their map as they gained more experience in collaborative concept mapping. The primary researcher was physically present for one large group experience and one dyad experience. Video or audio recordings of remaining experiences were obtained.

Concept Mapping Material

Due to the timeline of class curriculum, the first large group experience for the class was a concept map on changes in environment addressing disciplinary core idea ESS3.C. The Next Generation Science Standards (NGSS) for kindergarten, "Things that people do to live comfortably can affect the world around them. But they can make choices that reduce their impacts on the land, water, air, and other living things.". The remaining experiences were on the weather targeting core idea ESS2.D, "Weather is the combination of sunlight, wind, snow or rain, and temperature in a particular region at a particular time. People measure these conditions to describe and record the weather and to notice patterns over time".

We created a list of key concepts (i.e. idea units from the lesson), the print pictures that represent these concepts, target relationships between concepts that we want students to identify (learning objective), and linking words that describe the relationship between concepts for each concept map in collaboration with the teacher. For example, for the core idea ESS2. D, the teacher chose to focus on the learning objective: Students must identify different weather conditions and how their activity is influenced by the weather. The key concepts identified included sunny, rainy, cloudy, windy, snowy, beach, snowman, umbrella, kites, and dull (denoted by a grey block). We searched for, decided, and printed images representing these concepts which students can use to create their concept map. Lastly, we worked with the teacher to identify linking words which kindergarten learners could read. Including linking words in concept maps was optional for learners. The development of concept mapping material was done during a professional development workshop for district teachers in the summer preceding this experiment. We shared a completed concept map for each unit for the teacher to use as reference (see Figure 1 for an example concept map). Based on learner progress, the teacher worked with the researcher to include more concepts (such as the seasons) and words (such as the title 'Weather'). These additions were outlined in the procedure section above.

Measures and scoring

Critical thinking skills of analysis and interpretation were assessed by breaking them down to three reasoning skills familiar to learners: evaluation of logic, logical reasoning, and analogical reasoning. Researcher-developed worksheets containing eight questions each were used as pretest and posttest. These worksheets were piloted and refined based on feedback. Additional details are provided below for each worksheet.

Worksheet A. Evaluation of logic questions

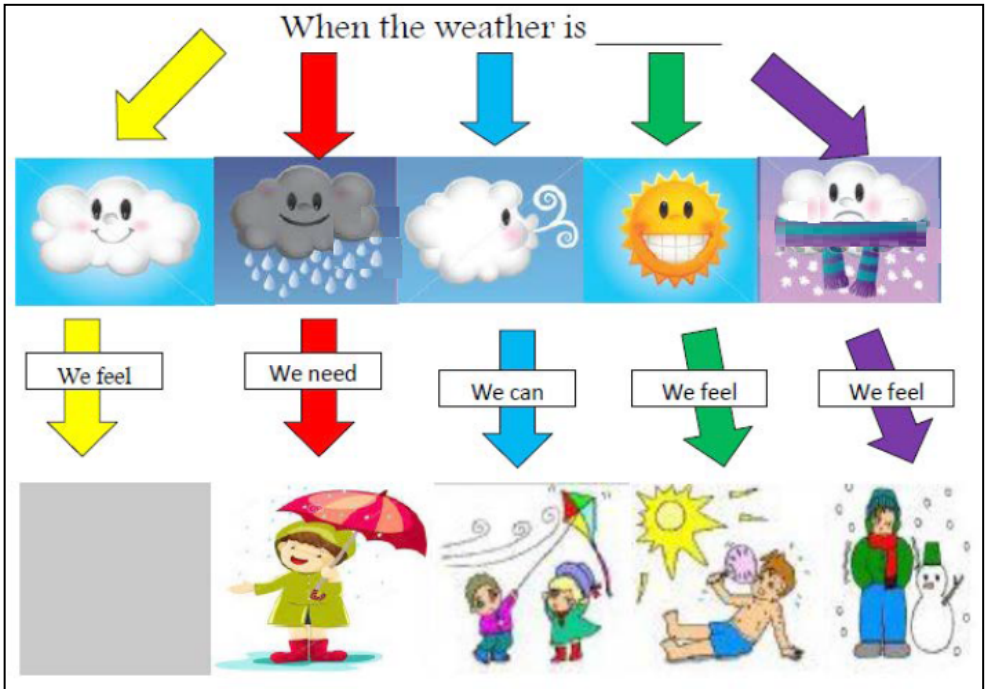

Figure 1. Teacher reference template for weather concept map

required learners to examine ideas (analysis), decode significance of the information presented (interpretation), and identify, make, and support a claim (analysis). Responses to worksheet A (Cronbach's α = 0. 82) were scored on the reasoning provided for the response and not the chosen response itself. For example, a question (see Figure 2) listed green peas, a green tree leaf, a green frog, and a yellow star. Learners were asked to cross out the one that does not belong and explain why they think it doesn't belong. Responses that provided a clear logic that can be independently applied to reach the same conclusion were awarded a score of one (e.g. "*you eat peas but you can't eat the other stuff*") and responses which were too broad or based on personal likes and dislikes were scored zero (e.g. "*peas are disgusting*"). Responses which provided contextually appropriate reasons were scored by the primary researcher and an independent rater. Once the two raters mutually ascertained the reasons were

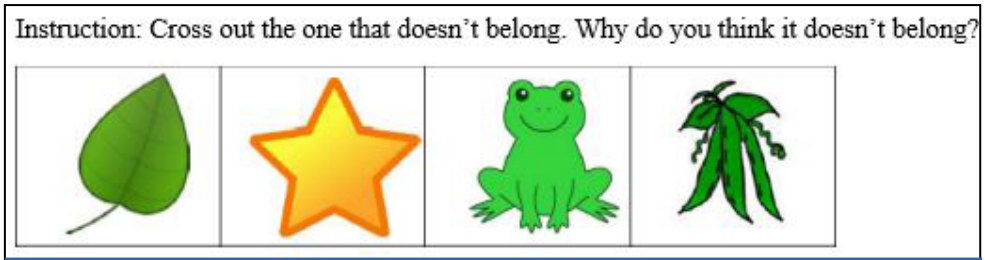

Figure 2. Example question in worksheet A (Evaluation of Logic)

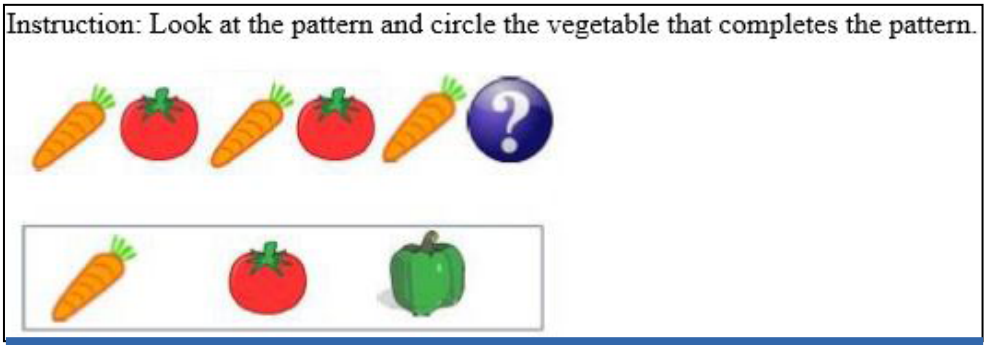

Figure 3. Example question in worksheet B/B1 (Logical reasoning)

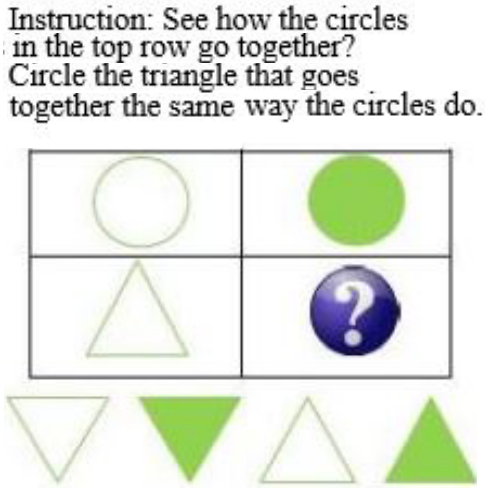

Figure 4. Example question in worksheet C (Analogical Reasoning)

contextually appropriate, these responses were awarded half a point (e.g."*peas are not high up in the air- frogs jump high in the sky and the star is in the sky and leaves are on trees*").

Worksheet B/B1. Logical reasoning questions (see Figure 3) required learners to identify the intended inferential relationships (analysis) between the objects presented. Since a majority of learners obtained a score of five or higher out of eight in the pretest worksheet B (α = 0.88), it would restrict potential to demonstrate growth post concept mapping experience if we retained the same worksheet. Hence, we created a posttest worksheet B1 (α = 0.57) in which we retained three questions and included five new questions. Since, there was only one correct response to complete the pattern (e.g. tomato in Figure 3), correct responses were awarded one point and incorrect responses were not awarded any points.

Worksheet C. Analogical reasoning questions (α = 0.78, see Figure 4) required learners to categorize (interpretation) and clarify meaning (interpretation) while identifying the actual inferential relationships (analysis). Since, there was only one correct response to complete the analogy (e.g. upright shaded triangle in Figure 4), correct responses were awarded one point and incorrect responses were not awarded any points.

Quantitative Results

The quantitative strand of this study sought to address the component question: *How do kindergarten learners' critical thinking skills of analysis and interpretation change across repeated collaborative concept mapping experiences in the classroom?* There were four missing values between pretest and posttest. We ascertained that data was missing completely at random (MCAR) $\chi 2 = 73.74$, $df = 58$, $p = .08$ by conducting Little's MCAR test (Little & Rubin, 1989). We used the PROC MI procedure in SAS 9.4 adopting Markov Chain Monte Carlo (MCMC) full-data imputation (Schafer, 1997) to create a multiply imputed dataset. Descriptive statistics from the multiply imputed

Worksheet	A (max = 8)		B (max = 8)		C (max = 8)	
n = 75	Mean	SD	Mean	SD	Mean	SD
Pretest	2.49	2.08	5.8	2.42	2.6	2.51
Posttest	4	3.03	5.73	1.45	5.35	1.73

Table 2. Descriptive Statistics

dataset are presented in Table 2 and were used for analysis. All assumptions for conducting a multivariate analysis of covariance (MANCOVA) except random sampling were met. All results were considered for statistical significance at alpha = 0.05 and confidence interval is provided for the effect size, Cohen's d.

A MANCOVA with age as covariate illustrated a statistically significant difference between pre and post-test; Pillai's Trace $F\ (3,146) = 24.13$, $p < 0.001$, $d = 0.79$ (CI: 0.47, 1.13) with learners performing better at posttest. Pairwise comparisons did not reveal any statistical significant differences for any of the three worksheets. This suggests that learners' performance in critical thinking increased overall post collaborative concept mapping experience.

Qualitative Findings

The qualitative strand of the present study primarily sought to answer the component question: *How do mentorship, discussions, and real life experiences shape collaborative concept mapping in a kindergarten classroom?* To address this question, we analyzed data from observations, field notes, concept maps, audio transcripts, and videos. We did axial coding of the data collected grouped in themes of mentorship, dyad discussions, and real life scenarios guided by Abrami et al. (2015) to understand the context and consequences of influences in the concept mapping process. Additionally, we open-coded the learner constructed concept map on the basis of number of concepts used, number of arrows used, number of levels presented, changes in structure of concept map over repeated experiences, and whether the dyad concept maps were structured similar to the large group experience concept map. To attempt credibility and trustworthiness, all sources of qualitative data were triangulated, and data collected was member-checked whenever possible. The primary researcher engaged in regular peer debriefing with multiple peers, experts scrutinized the project through its progression, and the primary researcher engaged in regular reflections on the methods, procedures, and resulting consequences.

Next, we report findings on the role of mentorship, discussions, and real life scenarios in enabling the collaborative concept mapping process followed by a brief synopsis of how the concept map structure changed at each dyad experience.

Mentorship

In both large group experiences, the teacher modeled the process of collaborative concept mapping and encouraged critical thinking through her think-aloud and questioning. This interactive demonstration primed learners to construct and read a hierarchical concept map. At the outset, the teacher started the concept map construction by announcing, "*I have these pictures and I need help figuring out where they go*", inviting learners to work together. In order to explain what the learners were to do, the teacher stated, "*We need to figure out where things go and how they make sense together.*" Then the teacher encouraged learners to reflect on their observations by asking questions such as, "*You said you saw litter on the ground, is that a good change*?" Then started negotiating map construction by asking questions such as, "*What causes that?*", "*What else can that be caused by?*", "*Who does that?*", and, "*So, where would it make sense, maybe if it were under people*?"

Sometimes when learners used concept words different from the ones provided by the researcher, the teacher helped learners make the connection between the concept they mentioned and the one the researcher provided. For instance, a learner mentioned that the grass they saw grow out of cracks in their playground was "*caused by trees and roots*", the teacher helped reconcile the concept with that of plants (researcher provided) by saying, "*That is part of plants, you are correct*." In other instances, a learner said that the environmental change can be "*caused by persons chopping down trees*", and the teacher narrowed it down to humans (researcher provided concept) by saying, "*Chopping down trees- that would be people*."

When learners were stuck on one concept, the teacher read out their constructed concept map and then re-directed their attention to another concept. For instance, the teacher would prompt by asking questions such as "*What do animals change nature for? What do animals give us*?" When learners took time to respond, the teacher proceeded to ask, "*Do animals give us clothes? House? Food?*" In response, all learners in class said "*no*" to clothes and house provision and most learners said "*yes*" for food. One learner, however, raised the point that "*animals are food*" which nurtured discussion about animals as providers of food and as food itself. When the teacher raised the question "*Who will make houses*?", one learner said "*animals*" while another said "*people*", raising a moment of (cognitive) conflict for the group which the teacher helped resolve by discussing how both animals and people make different types of houses.

Experience Discussions

In the first large group experience, we observed that learners did not connect the relationship between humans and clothes (i.e. humans use environmental resources to make clothes). This then provided an opportunity for the teacher to talk to learners about how plants are used to make their clothes, addressing a gap in learner knowledge. Learners welcomed the new information with surprise and had group discussions about it. In the second large group experience, we observed that learners tended to see the relationship between concepts as pairings, e.g. sunny – beach, and did not have much discussion.

In addition to learning new concepts, collaborative concept mapping highlighted the relationships learners identified through their discussion. For instance, during the third dyad experience, one dyad demonstrated an understanding of the seasons sequence by placing arrows stating "*because after winter is spring*". The dyad also connected the concept grey with spring explaining: "*Spring? It's dark when it rains*", demonstrating their perception of the relationship between the weather and the environment. Another dyad placed an arrow pointing from a regular cloud to grey concept and interpreted the relationship as "*It's a storm fog*", while the teacher presented this concept pair with the idea, "When cloudy, it's grey outside". A third dyad did not include the image for 'grey' and 'cloudy' concepts. When asked, the dyad explained that the 'grey' refers to "*Darkness. Nobody likes this dark*", and since cloudy goes with grey, they chose to exclude the cloudy concept. While this dyad may not have focused on targeted conceptual connections, their discussion provided insight into how learners personalized their learning as reflected in their choosing to exclude concepts.

These dyads, like most others in the third dyad experience, analyzed the given concept pictures independently, interpreted the potential relationships between concepts, and placed as many as they could, unlike the first dyad experience where most dyads replicated the large group experience map and explanations. With more familiarity, learners identified and resolved gaps either between themselves through discussion or by asking the teacher. This process exhibits how learners practiced critical thinking skills of analysis and interpretation and the central role of discussions and mentorship in facilitating the practice.

Additionally, peer discussions also provided dyads an opportunity to explore their creativity. A dyad in the third experience created a story by personalizing the given concepts with character names and associations. For instance, they referred to winter as "*Christmas pictures*", and referred to snow. One learner mentioned that it snows on Christmas while the other learner paused and then responded, "*Not every time but this Christmas, it is snowing so very much*". This lends evidence to learners' skill to process and individually analyze information even as they collaboratively construct their concept map. Further, they explained that they identified certain pictures to denote

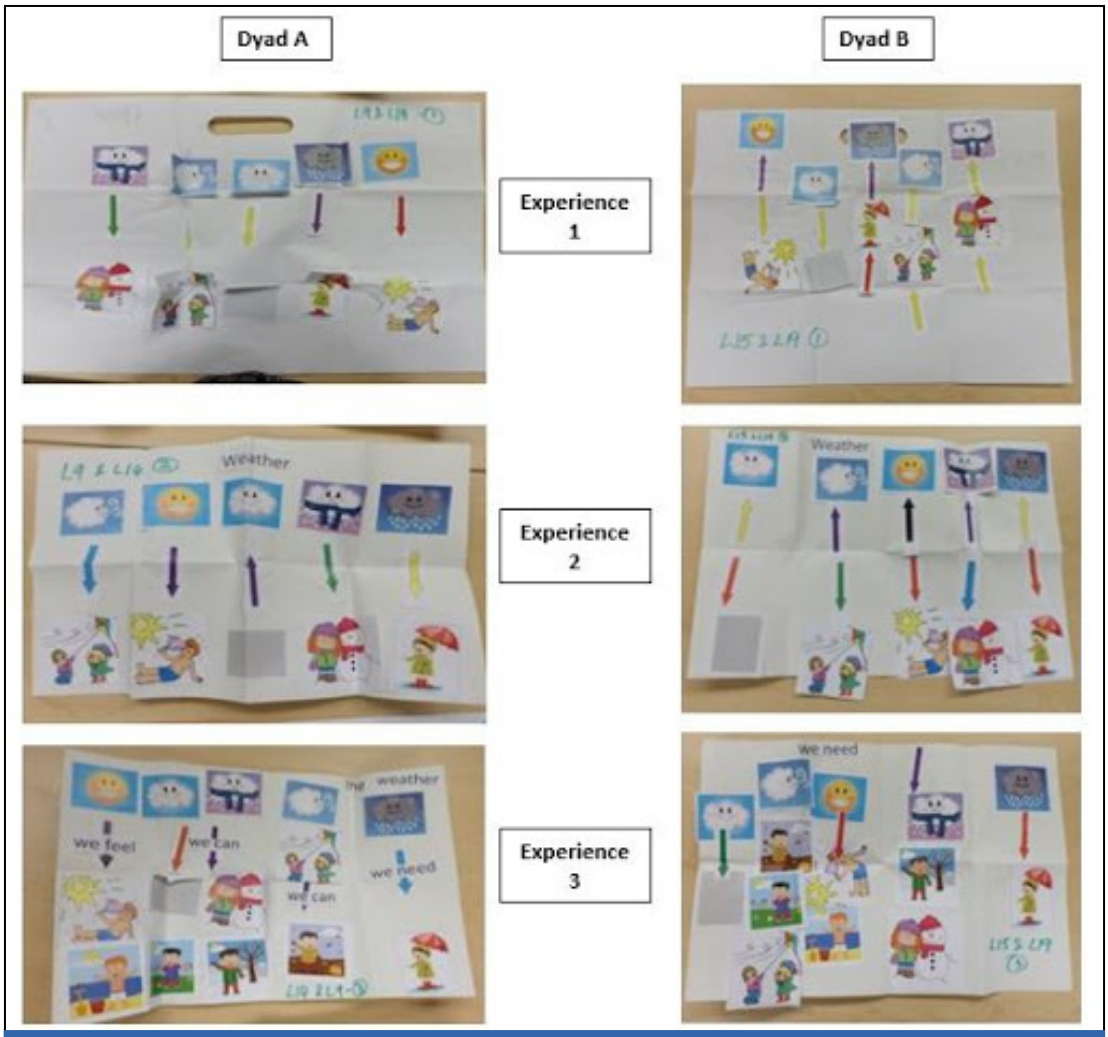

Figure 5. Examples of dyad's concept maps through each exposure.

summer, "*By him being hot, him picking flowers and him playing at the beach.*" This demonstrates learners' ability to analyze and interpret the provided images to represent specific concepts narrated from their prior knowledge, which in this case was from real life scenarios.

Real life scenario

Prior to the first large group concept mapping experience on *changes in environment*, learners went on a neighborhood walk to identify how their environment had changed in the past week. For the second large group and all dyad concept mapping experiences, no specific experience was designed since learners recorded the weather on a classroom chart every day as part of their regular instruction. These experiences allowed learners to gain prior knowledge creating common ground for discussions, as outlined in detail in the 'Dyad Discussion' section. We also noted that the teacher had changed the description of the connection cloudy – grey from the researcher provided 'it's grey outside' to 'we feel grey when it's cloudy', highlighting how different individuals may perceive and use given images differently, based on prior knowledge and experience.

Dyad concept map structure over time

The weather concept map was constructed in a large group as well as in dyads. The dyad concept maps changed in structure for most pairs of students with increased experience, as evidenced in Figure 5. In the first dyad experience, most learners referenced and replicated the structure of the large group concept map. They referred to the concept map as a "*chart*" in which they matched a concept (weather) to another associated concept (activity) rather than as a map of concepts. When asked to read their concept map, one dyad said, "*we tried to make it the same as that one*". We also noted that many learners had trouble spacing their concept map so as to fit all pictures neatly on the sheet of paper provided.

In the second dyad experience, we observed that several dyads constructed and read their concept map similar to the large group experience. However, learners were better able to organize the space on their paper to fit all concepts in their concept map. A few dyads chose to experiment with their arrows by changing directionality of relationships or by establishing bi-directional relationships in the second dyad experience (see Figure 5).

By the third dyad experience, the concept map structure began to differ across most dyads. One dyad paired their concepts horizontally rather than vertically as demonstrated in the large group experience. Another dyad placed arrows like a (+) plus sign and explained, "*once you go down this way, you go this way*", identifying the direction of flow of concepts but not the nature of relationships between concepts. Nevertheless, we infer that this dyad understood the directional role arrows play in concept maps and created their own unique structure. Another dyad seated at the same table mirrored the structure but were unable to replicate the explanation highlighting the importance of asking learners to read or explain their concept maps. Lastly, when triangulating the sources of data, we observed that dyads who had rich peer discussions (as described in the dyad discussions) changed their concept map structure and were able to explain their decisions, highlighting the role of dyad discussions.

Meta-inference

The present study is guided by the overarching research question: *What is the role of collaborative concept mapping in the development of kindergarten learners' critical thinking skills of analysis and interpretation in* the

classroom? Inferences drawn from quantitative results and qualitative findings suggest that collaborative concept mapping, particularly when the concept maps are developmentally appropriate and construction is supported by mentorship, discussions, practice, and when based on real-life scenario, encourages young learners to demonstrate their critical thinking skills of analysis and interpretation.

Discussion

By breaking our guiding question into two component questions focusing on outcome and process, simultaneously investigated using a parallel mixed method design, we are better able to understand the role of concept mapping in the classroom. We recorded a large effect size $d = 0.79$ (CI: 0.47, 1.13) when comparing kindergarten learners' scores on measures of critical thinking skills of analysis and interpretation before and after the weekly collaborative concept mapping experiences over five weeks. Young learners demonstrated change qualitatively during each experience which allows us to understand the role of reflecting on real life experiences by engaging in discussions supported by mentorship to facilitate critical thinking instruction as suggested by Abrami et al. (2015).

For instance, reliance on the large group's concept map and the similarity of the dyad concept map to the large concept map in the first dyad experience raises consideration of the importance of and the quality of mentorship (including modeling and scaffolding) provided through the large group experiences prior to allowing learners to concept map on their own. In the second dyad experience, growth in learners' layout capabilities in using the space provided as well as changing arrow directionality from the large group concept map suggests that repeated experiences of learners actively engaging with content promoted their independent thinking. Further, the changes in content and structure from the first to the third dyad collaborative concept mapping experience highlight how the learner's individual understanding showed their application of analysis and interpretation skills across multiple experiences of the concept mapping process and the concepts themselves.

Real life scenarios provided learners prior knowledge which supported appropriate scaffolding and modeling (mentorship) and translated to rich discussions. Discussion generated from open ended scaffolding questions encouraged learners to think of and suggest possibilities which demonstrated their understanding (interpretation) of concepts, their analysis of the outcome, and the relationship between their interpretation and analysis of concepts. The difference in amount and quality of discussions in the two large group experiences prompts consideration of the number and levels of concepts involved in relation to group size, which may be an area of future investigation. Nevertheless, discussions in large groups and in dyads allowed the teacher to identify and correct misconceptions or misrepresentation of concepts, or provide additional information related to their unit, demonstrating the value of concept maps as formative assessment tools (Authors, 2013; Canas & Novak, 2010).

The examples we presented demonstrate personalized interpretation of images highlighting the value of discussions in meaning negotiation during concept map construction, as suggested by Authors (2013). Such negotiation of meaning allowed learners to construct their own unique concept maps despite using the same images. When learners analyzed the connections between concepts and try to create their own mental construct (Novak & Canas, 2008), they interpreted and presented images differently as familiarity with the concept mapping process, images, and concepts increased leading to diverse concept map structures. The difference in explanations and structure of concept maps also illustrate the role of hands-on engagement during concept mapping in dyads to promote processing of concepts and practicing critical thinking skills of analysis and interpretation.

Further, the curriculum shaped the first large group experience (changes in the environment) by enabling a more robust modeling of the concept mapping process using more and multidimensional concepts facilitating the frequent demonstration of associated critical thinking skills than what was feasible with the second large group experience (weather). Moreover, teacher enthusiasm and pedagogical style may have influenced the modeling of large group concept maps that may have consequently instigated learner engagement in subsequent experiences (Bandura, 1986; Rosenthal & Zimmerman, 1978; Schunk, 2012). For instance, we observed that the teacher asked questions similar to those listed by Facione (2010) to encourage critical thinking skills and dispositions on their own. We highlight that this study was conducted in the natural flow of the kindergarten classroom with the teacher leading the intervention with little training, emphasizing the ecological validity of the instructional strategy's implementation.

In conclusion, when we observe the change in demonstration of critical thinking skills of analysis and interpretation across concept mapping experiences quantitatively and qualitatively, we infer that it is likely that the repeated experiences provided opportunities for cognitive engagement and discussions guided by learner understanding of concepts, direct negotiation of meaning, and identification of interrelationships between concepts as expected in a collaborative concept mapping experience (Cañas et al., 2003).

Limitations

As with all research, our study has certain limitations. This study was conducted in a largely white, low-income population, restricting the generalizability of our findings. Additionally, due to limited resources, the audio or video recordings of dyad experiences captured information for a limited period of time for each dyad restricting our ability to speak to only a part of learners' experience. Further, in our attempt to address missing data, we are aware that the multiple imputation techniques may have increased power to an extent where small differences were detected as significant. Lastly, while we recognize that our within group design does not allow us to explicate the effect of collaborative concept mapping from potential effects of maturation and other classroom activities, our design promotes evidence-based ecological validity suggesting effectiveness in the classroom.

Implications

This study provides preliminary empirical evidence to support concept mapping as an instructional strategy teachers may employ in elementary classrooms (particularly kindergarten) to encourage the development of critical thinking skills of analysis and interpretation. By adopting a parallel mixed method design, our study provides a more in-depth understanding of the role of concept mapping than the prevalent single method research studies. Further, we believe that adopting a mixed method approach allows researchers and practitioners to visualize how collaborative concept mapping occurs in the classroom as well as its plausible impact on critical thinking skills. In this way, the study adds to research literature on concept mapping as well as young learners' critical thinking. Lastly, this study contributes to practice by establishing that collaborative concept mapping can be implemented successfully by teachers in classrooms over time on subjects required by state standards while developing critical thinking skills, even if teachers do not have much training in concept mapping, as was the case in this study.

Future Directions

Future research should include a comparison group to more rigorously examine the extent to which concept mapping shapes the development of critical thinking skills. In addition, it will be interesting to measure content learning gains to investigate the extent to which concept maps help meaningful content learning in kindergarten. Future research may replicate this study and attempt to delineate the role of learners' individual differences such as age, gender, academic standing, verbal ability, intelligence, critical thinking dispositions as well as characterize the impact of classroom elements such as teaching style, teacher training, teacher self-efficacy and classroom environment on the effectiveness of collaborative concept mapping.

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