Learning and Thinking in Practice: Complex Systems Thinking "In the Wild"

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Abstract: Research in the field of learning sciences demonstrates that various forms of knowledge are created through participation in diverse but often undervalued community practices (Nasir, Rosebery, Warren, & Lee, 2006). However, knowledge created in practice is not traditionally explored in research about complex systems thinking (Duarte Olson, Forthcoming). This session seeks to recognize and capitalize on the wealth of complex systems knowledge learned through everyday practices in informal contexts. We present arguments that are grounded in research taking place in four different communities—with Brazilian samba schools, triathletes, Native Americans, and environmental educators. The goal of the symposium is to discuss (1) how complex systems thinking can be developed through different practices in informal environments, and (2) how an under-representation of diverse samples and phenomena may eschew our understanding of complex systems thinking.

Symposium Overview

The learning sciences community has long suggested that knowledge arises from engagement with cultural practices both within and outside of school settings (Bang, Medin, & Atran, 2007; Nasir et al., 2006) However, most studies on complex systems, focus on how students think about scientific concepts learned in formal environments (Duarte Olson, Forthcoming), with very few papers specifically targeting knowledge of complex systems acquired in informal contexts (Bang et al., 2007; Duarte Olson, Submitted; Olson, 2013). The body of research on complex systems thinking is valuable and informative, however work on how individuals construct complex knowledge in everyday or out-of-school contexts is necessary for the design of more equitable learning environments. Although the knowledge gained from community participation is often analogous to that taught in schools, it is sometimes undervalued (Nasir et al., 2006). Despite the lack of research on everyday knowledge of complex systems, this knowledge is necessary because informal learning practices developed within family and community systems are conducive to systematic and reliable scientific knowledge and important for the development of skills for science (National Research Council, 2009). Moreover identifying this knowledge as scientific could create new paths for diverse communities to embrace STEM careers.

This session is aimed at demonstrating how community practices are an asset and a locus of complex knowledge development. We take on the challenge of discussing how complex systems knowledge can be developed in informal settings with four different studies taking place in diverse community settings. Although the studies approach distinct complex systems, all of them have the same overarching theme: How complex systems can be learned through engagement with a practice. These practices include engagement with the Carnival parade in Rio de Janeiro Brazil, biking in groups, play between children and parent dyads, and teaching climate change. Each of the studies also utilized a wide range of methodologies, ranging from agent based modeling to ethnographic methods, to examine how different practices across 4 different communities afford the construction of complex systems knowledge.

Taken together, the five papers illustrate a wealth of knowledge and a variety of practices cocreated within the diverse communities represented. In the first session, we will discuss how expert samba practitioners understand auto-regulation through their understandings of the relationship between samba school and the audience. We focus on how experience with the samba parade shapes more complex understandings of auto-regulation. The second session explores how a community of triathletes used agent-based models to understand the complex phenomena of drafting to increase comprehension and performance. The third session illustrates how Native American children and parents reason about ecological relations that appear in spontaneous play. Finally, the fourth session discusses how a professional development course on climate change can have a profound impact on teachers' understanding of this complex phenomenon. With this, we hope to create a venue to discuss (1) how informal contexts foster the development of complex systems thinking, (2) issues of cognitive diversity in thinking about complex systems, (3) how to use this knowledge to inform design in the Learning Sciences.

Becoming Samba: Understandings of the Process of Auto-Regulation through the Relationship between Audience and School

Izabel Duarte Olson and Ananda Marin

Escolas de samba (or samba schools) are community-based organizations in Brazil. These schools spend an entire year preparing for the samba parade, which occurs yearly during the carnival. They start the year by choosing a theme and creating a *samba enredo* (a theme song). The theme song is usually practiced all year along with any choreographies needed to perform it. The climax is the samba parade, which happens yearly during the Carnival. During this event, schools are judged and ranked with an overall winner. Eighty percent of the school's success is judged by its "harmony" or the way that the members are in synergy with the rhythm, the theme song, themselves, and the audience. Although Rio de Janeiro is a very segregated city, samba schools are a democratic space bringing together working-class and middle-class communities, diverse races and creeds.

Figure 1. The Samba Parade in Brazil

Even though the carnival is purposeful and planned, it is a great site for studying complex systems thinking in the wild as the symbiotic relationship interconnecting audience, school, and each individual member, is what makes a school an overall winner. Moreover, the samba parade is a cultural phenomenon where an enormous amount of complex coordination happens among dancers and mediating structures found in the parade (Hutchins, 1995). Mediating structures are external tools that help one navigate an activity. In the samba parade these structures include the floats, the audience, the section directors, and the beat coming from the instrumental section. Initial fieldwork suggests that there is an unending concern to preserve the emerging unity of the school through coordination among its participants. This coordination among participants allows information to be propagated through these mediating structures with the goal of creating a symbiotic unity in the school, which they call harmony. The result is described as a live organism.

Understanding this live organism requires a decentralized understanding of these coordination processes. With that, the carnival parade could be considered one of the largest participatory simulations in the world. This symposium presentation will explore expert practitioners understandings of the auto-regulation process that results from the schools relationship with the audience. More specifically, we will explore the role of their practice in constructing those understandings. During the parade, the audience functions as a means of feedback. The way the public reacts informs the component of the school's performance, allowing the components of the school (e.g. each individual floor component, section directors) to adjust their actions. During fieldwork, the way the audience reacted greatly shaped what happened on the parade floor. For example, if the audience was animated, the components fed into the audience's reactions and grew. In instances where the audience was cold, the components sensed that and became equally cold.

In previous research, the first author investigated working-class and middle-class individuals understandings of socio-economic mobility. Mobility practices were found to distinctly shape people's understandings of complex phenomena (Duarte Olson, Submitted) as navigating different contexts correlated with more evidence of complex systems thinking. We believe practice also shapes expert Samba practitioners understandings of the samba parade in Rio de Janeiro. Our hypothesis is that our informant's roles and years of practice will be correlated with their understandings of the relationship between audience and school.

Methods: Population

In-depth interviews were conducted with 52 individuals who had a high degree of involvement with one of Rio's *samba* schools. A high degree of involvement was established by how many years they have been participating in the carnival. At least five consecutive years of participation in the parade were necessary to establish a high degree of involvement with the school. Twenty-three participants were women, while twenty-nine were men. The mean age of participants was 46 years old with an average 25 years of experience in the samba world. As perspective-taking is important for complex systems thinking (Duarte Olson, Submitted) participants had purposefully different roles to see if one's role affects their understanding of the parade.

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Sampling

The sampling was purposive. Initial contact was established with several section directors from samba schools, including Salgueiro, Unidos da Vila Isabel and Beija Flor. Based on these initial contacts, potential participants were found through word of mouth and a snowball sampling technique. Participants were not paid for their interviews.

Materials and Procedure

Participants were initially contacted through a referral. Then, if the person agreed, they were later interviewed in their homes, the school, or another location of their preference. The interview instrument consisted of fourteen open-ended questions that examined how individuals reasoned about the relationship between harmony and evolution, audience and school, and the overall interconnectedness of the school. The present research will examine responses to the fourth question in this interview: "Does the audience have a role in the parade? If so, why do you think that?".

Coding

The interviews were transcribed in Portuguese and later translated to English. The goal of the analysis was to understand how experience (indexed by years) and the participant's role shape complex knowledge of a practice. To accomplish this goal, the responses were divided into clauses and a code was assigned to each one. As there were differences in the length of the responses, the raw data was normalized by dividing the code clause count by the total number of clauses in each response. Five codes attended to the relationships each participant noted (e.g. Influences from public to school: If the public embraces the school, the school grows or Influence from one component to school: "But that singer sang so well he exhilarated the school"). One code attended to participants' use of emergent concepts. For example, "We become samba" notes the emergence of a characteristic that goes beyond the school

Results

Understanding the idea of emergence in Samba seems to be correlated with the amount of experience participants have (indexed by years of practice), but not with their actual roles. We ran a 2-way ANOVA with years of practice and role as an independent variable, and the emergence code as a dependent variable. We got a main effect for years of practice ($F(1, 25) = 2.916$, $p = .1$). This is evident in the way this 63 year-old woman, who has been in the samba world for 50 years, talks about the relationship between the school and the audience: "The audience moves the school, the school moves the audience, together we become samba." She sees samba as an emergent property of the synergy between school and audience. These two are linked together in such a way that there is no samba if one of the pieces is taken away.

When speaking about this relationship, participants often noted how each component of the parade affects one another. Participants with more experience, quantified by years of practice, were also more likely to mention more types of influences. A 2-way ANOVA found a main effect for years of practice ($F(1, 25) = 5.43$, $p = .03$), but not role. The more years of experience a component had, the more types of influence the person mentioned. Take Alan's response, who is 33 and the leader of the instrumental section at a major school of samba in Rio. Alan has been in the Samba world since age 1: "If the public is with you, they sing, if the samba is good, if the school is in a good moment, if the public embraces the school, it is easier. The judges think: Well, I can't go against this school, because the majority is with them". Alan, who is an experienced samba practitioner, talks about 4 different relationships when explaining the role of the audience. Most often participants with less experience noted one or two relationships. For example, Ary, a 58-year-old who has participated in the parade for 8 years only notes a one-way relationship between audience and school: "Their role is of motivation […]."

The role of participants was not correlated with their understanding of their practice. Maybe because during rehearsals there is not much distinction between roles, unless you are part of one of the more specialized sections (e.g. instrumental section). Therefore, the interaction that is consistent six months out of the year is more crucial in shaping your knowledge of samba than what happens in 30 minutes during the parade floor. However, experience was predictive of people's understandings of emergence and the number of relationships people mentioned in their response. Practitioners that had more experience (indexed by the number of years in the practice) were more likely to mention emergence and more relationships. This paper shows the importance of practice in learning complex systems thinking knowledge and invites the learning sciences community to look for more that are the locus of complex systems knowledge development.

Collaborating while Competing: Conceptual and Motor Learning While Inventing Drafting Tactics with Agent-Based Models of the Aerodynamics of Bicycle Drafting

Alon Hirsh and Sharona T. Levy

Can a constructionist complex systems approach support better understanding and performance in sports? In this paper, we describe research into young triathletes' invention and execution of new drafting tactics using computer models based on a complex systems approach. The tension between cooperation and competition invoked while biking in groups within a triathlon competition is problematized as a substrate for learning regarding the aerodynamics of collective motion through air. The present study presents a curious finding that runs contrary to well-established motor learning theory (Schmidt & Wrisberg, 2008) that claims that conceptual learning precedes and promotes motor learning: how learning through constructing collaborative tactics for overcoming air resistance via a complex systems perspective enhanced athletes' biking performance but not their conceptual understanding of the very same topic.

The study involves a model-based triathlon training program, Biking with Particles, concerning aerodynamics of biking in groups (drafting). A conceptual framework highlights several forms of access to understanding the complex system (micro, macro, mathematical, experiential) and bidirectional transitions among these forms, anchored at the common and experienced level, the macro-level (Levy & Wilensky, 2009). The goal was to explore whether using agent based models of bikers and air particles to learn about drafting could be used to enhance athletes' understanding and performance. Motor learning and conceptual learning of the aerodynamics of drafting were compared.

Triathlon and Drafting

The triathlon is a multisport event, which was established some 30 years ago. The three disciplines in the event are swimming, cycling and running. A triathlete performs the three sports in the specified sequence and strategizes effort and speed to obtain maximum effect in minimum time. The distance in each sport is determined by age. In the adult category the distance for swimming is 1500m, cycling 40km and 10km for running. In the current study, our participants were youth and performed 50% of the adult requirements in competitions. The term drafting is mostly used in the field of physiology and biomechanics of sports to name the movement of closely packed individuals aimed at aerodynamic protection (Hausswirth & Brisswalter, 2008). A peloton is a large group of cyclists that are riding together to create a network that spreads energy resources among the cyclists. A peloton is usually created spontaneously. One of the main reasons for losing energy during cycling is due to friction with the air. The aim of drafting is to reduce this friction. Little research has been conducted into the impact of drafting in triathlon on physiological factors.

Cooperation/Competition

Drafting is used to gain energy advantages in moving through the air (Hausswirth & Brisswalter, 2008). The phenomenon of drafting offers unique insights into the delicate balance between competition and cooperation among collectives. On one hand, drafting offers up to 40% savings on energy expenditure, rising with the biker's speed (McCole et al., 1990). On the other hand, the group speed may slow a biker down too much; in which case, a smaller group may "break-away" usually around a bend in the road. Thus the persistent question for a given cyclist is "stay or break away". Furthermore, the answer can change at any given moment. In a triathlon (sequenced as swimming, biking then, running), biking at a less than maximal rate and minimum energy expenditure is particularly advantageous in saving energy for the last leg of the competition.

Conceptual/Motor Learning

This study examines both conceptual learning and changes in performance. Performance is viewed through the motor program construct (Schmidt & Wrisberg, 2008). The motor program is an abstract representation of movement, used to describe cognitive processes in movement planning that include both pre-programmed movements and responses to environmental stimuli. This construct is central in sports research. It is fundamental to the current study as we expected that the resulting motor program would include greater flexibility with respect to environmental conditions, sensations with respect to air pressure, and flow. This flexibility is related to both sensing of input (sensorial input related to the tactile and haptic senses) and to related movement, such as shifting position to better locations within a configuration. Motor learning is described as having three stages: (1) cognitive-verbal; (2) motor; (3) autonomous. Within this study, we have focused on the first stage, cognitive-verbal learning that may take place through exploring and discussing computer models. In the cognitive-verbal phase, the learners do not yet know the topic and skill they will learn. During this time they talk to themselves, ask questions about confusing issues and ask self-monitoring questions. In Biking with Particles, we have provided a learning environment that encourages such talk and questioning, by providing several opportunities to self-explain, explain to others, listen to and assess explanations (Chi & VanLehn, 1991). Perceptual learning

and conceptual learning are also conceptualized as part of motor learning. In the early stages of motor skill learning, the athlete needs to experience the skill at the conceptual and perceptual level (Schmidt & Wrisberg, 2008).

Expert/Novice

It has been claimed that in most fields of sports, athletes need to process information very quickly in an environment where time is a crucial factor (Williams et al., 2010). Therefore, athletes need to adapt themselves to unique constraints of the task by learning knowledge structures and cognitive processes that support their prediction of what will happen and deciding on the appropriate choice of action (Williams & Ford, 2008). The above researchers claim that experts circumvent the limitations of short-term memory by learning skills that facilitate quick processing of information into long term memory and selective access to this information, as needed. After extended practice, experts tag information in such a way that enables anticipation of when it will be needed in the future. In a meta-analysis of the relationship between expertise and perceptual-cognitive skills, several distinctions were found among novices and experts in various domains in sport (Mann et al. 2007). Notably experts were better at identifying perceptual cues.

Training was conducted separately with two groups, both 14-17 years old youth: an elite junior triathletes team (experts; 4 male, 3 female) and a local team (hobbyists; 6 male, 3 female). The study lasted three days and included lectures, discussions, guided exploration of agent-based models of concerted motion through air particles (Levy, Hirsh, Bacalo & Kakoon, 2011), inventing new tactics, and biking in practice. Data included questionnaires, interviews, videotapes, and performance measures of heart-rate and biking duration.

The athletes' invented designs were innovative and diverse, expressing well-known (diagonal placements, one-behind-the-other units, aerodynamic group contour, rotation in motion) and new features (wrap the weak, strong in front) in the sport. Local features (e.g. diagonal placements) were more dominant than global features (e.g. aerodynamic group contour). While displaying some well-known principles, the tactics themselves were original, new to the sport. The athletes' designs introduce new tactics of drafting that incorporate an idea of uneven load distribution. In optimizing a solution that balances across the tension of cooperation and competition, the weaker cyclists' performance that is detrimental to the group was alleviated by creating vacuum bubbles. These bubbles were used to encapsulate the weaker riders, making it easier for them to ride, without impacting the group performance. A heavier load was placed on the strongest riders, while negotiating the energetics of this arrangement to make sure the strong bikers still obtained energetic benefits.

Their performance in bicycle drafting increased dramatically, with a gain of 20%, at both individual and group levels. The experts mainly reduced their times. Hobbyists mainly reduced their effort. The gain was measured with respect to the currently known best drafting tactic, the Belgian Tourniquet – named, BT (Hausswirth et al. 2001) that involves rotating placement and leadership within an ellipse of bikers. Computation of this efficiency was based upon the ratio of output to input; the invested effort (input measured as heart-rate from resting baseline) and the performance outcome (output in terms of speed or time) thus introducing a concise new efficiency measure into the field of sports. For each group, the tactic with the best efficiency was compared with the BT. The experts improved in efficiency by 19%. The hobbyists improved in efficiency by 20%. For each athlete, the best efficiency among all invented tactics was recorded. The mean efficiency was .99 (.18), with higher mean efficiency for the experts [1.13 (.11)] than for the hobbyists [.86 (.13)], with an unpaired $t(11) = 4.01$**.

Some conceptual change was evidenced for the micro-level complex systems components (particulate nature of air, paired $t = 2.43$*), and micro/macro relations (paired $t = 3.74$**) but not regarding how these emerge into drafting patterns. Generally, the athletes' explanations of drafting from the more basic definitions and until more complex problem solving did not change.

We had found the triathletes' designs to be innovative, proliferate, and diverse. Their inventiveness goes beyond the single and double line, or the BT described for triathlon competitions. Older central triathlon coaching texts do not mention drafting at all. The newest coaching text to date (US Triathlon 2012) describes only the rudimentary tactic of a single line. As drafting is a relatively new and still-contested feature in triathlon competitions, it seems that there could be much room for growth. The junior triathletes introduced several new tactics into the field of competitive bicycle riding in triathlons, a significant achievement.

We have seen a radical change in performance, not usually evidenced in the domain of competitive sports. The triathletes improved their efficiency (speed with respect to effort) by 20%, both as a group and as individuals. Improved performance is related to greater speed, expending less effort, and staying within the aerobic range. A methodological contribution of the current study is developing a metric for the main factors as a single efficiency measure. This measure supports comparison between tactics.

One may wonder as to the small rise in conceptual understanding when such a large increase in performance was under way. While the athletes learned the basic physics of air particles' motion and could use the ideas of air density to understand effort, they did not improve their understanding of drafting. Motor learning has been described as going through three stages: (1) cognitive-verbal; (2) motor; (3) autonomous (Schmidt and

Lee 2011). It seems that in this study, the cognitive-verbal stage was cut short, and partly ‘‘skipped over’’ so that most of the learning happens at the motor stage. This finding begs the question of whether the first stage is a necessary pre-requisite for the second stage. It suggests that with motor skills, one does not have to verbalize what one understands in order to perform it. Processing in the motor learning stage involves making performance more adaptive and efficient. It would seem that the visual and spatial information provided by the models and completed by the athletes' imagination and mental simulation could be enough to create a solid basis for improved action. The highly visual and dynamic quality of the computer models leads to incorporating the ideas they offer into perceptual-motor schemes without going through the channel of verbal explanation.

Emergent Complex Systems Reasoning: Cross-Cultural Differences in Reasoning about Eating Relationships between Kinds

Megan Bang, Priya Pugh, and Douglas Medin

Although some scholars have argued that biology is a core conceptual domain that is organized in terms of universal principles of categorization (e.g. Berlin, 1992) and a domain which is associated with a universal developmental unfolding (Carey, 1985), there is accumulating evidence of broad cultural differences in knowledge organization and suggestive evidence on variable developmental trajectories (e.g. Medin and Atran, 2004; Hermann, et al, 2010). In our work we have been investigating the cognitive consequences of relational epistemologies on knowledge, knowledge organization, attentional foci, and sense-making about the natural world more specifically (Medin and Bang, in press). We have found significant cultural differences in conceptions of human/nature relations that are manifest in explicit knowledge and values and implicit in practices and conceptual organization (Bang et al, 2007, Medin et al, 2006). Further, we have found that rural Native-American children employ ecological reasoning developmentally earlier than rural, European-American children and that rural children in general use ecological reasoning earlier than urban (Non-Native) children (Ross, et al, 2003). In the current work we are hypothesizing that these differences in ecological organization of knowledge may develop from differences in psychological closeness and whether a systems perspective, focusing on relationships, is adopted. One way to study this is through the examination of young children and their caregivers communication and engagement in sense-making about the natural world. This study asked 61 parent-child dyads across two cultural communities to play with a 3-d diorama forest. The content and focus on the spontaneous talk during the task comprises the data for this study. To develop this work we briefly explain, what relational construals might mean and the specific domain of relational construals taken up in this study. Before we present our current work we also provide a brief overview of psychological distance and perspective taking. We develop predictions for the content and structure of the talk we anticipated given this theoretical background, discuss our methods, and present our findings.

Relational Construals, Psychological Closeness/Distance, Perspective Taking

There are various strands of work that contribute to our understanding of relational construals and this term is intended to incorporate this broader landscape. In part this terminology is drawn from ecological knowledge organization and reasoning patterns (Atran & Medin, 2008, Medin & Atran, 1999). Other work has explored associative relational patterns that children perceive in the world (i.e. Keil, 2003). Still other work has suggested that Indigenous thought is foundationally based on constructions and meanings of relationships (Cajete, 1999). For the present purposes we focus on the relational construals in the context of eating relations between kinds. Trope and Liberman (2003) proposed that psychological distance affects cognitive processing at least around physical distance, temporal distance and social distance wherein psychological distance is associated with attention to abstract features and the whys rather than hows of phenomena among other things. Psychologically close events are associated with (a) greater attention to context and mitigating factors and (b) a greater likelihood of interpreting social behavioral situationally rather than dispositionally. CLT is also relevant to perspective taking. For example, being in a position of power (by hypothesis, being more psychologically distant) may be associated with a failure to take the perspective of other actors or to take situational factors into account in judging the behaviors of others (Galinsky, et al., 2006). CLT predicts that psychological closeness facilitates perspective taking and there evidence suggesting that cultures differ in the ways in which they deploy psychological distance and perceptive taking (e.g. Masuda et al., 2008). There also are correlated cultural differences in the likelihood of spontaneously taking another person's point of view (Wu & Keysar, 2007; Leung & Cohen, 2007). In our work we have found that psychological distance impacts the features and content attended to in the natural world (e.g. Medin & Bang, in press).

Predictions

Given the cross-cultural differences around ecological knowledge organization, and the theoretical implications of psychological distance, and perspective taking, we predicted seeing the following differences between Native and non-Native dyads.

1. Native dyads would have more kinds (living things) involved in eating relations than non-Native dyads.
2. Native dyads would have a wider variety of forms of eating relations (e.g. food webs, food chains, etc.)
3. Non-Native dyads would demonstrate more psychological distance in the use of generic forms of kinds (e.g. bears), while Native dyads would use more specific forms (e.g. this bear).
4. Native dyads would demonstrate more spontaneous perspective taking measured by different ways of narrating eating relations and attention to internal states of the focal kinds.

Participants

This study engaged 40 Native American parent-child dyads and 21 European-American parent-child dyads. Native children and parents were recruited from the Menominee reservation and the Chicago Urban Indian community and from the town of Evanston, IL USA.

Materials

Parents and children were given a 3-d diorama about 1.5 feet long by 1 foot wide of a forest ecosystem that included stationary parts (trees, rocks, a pond, a log) and moveable parts (trees and animals including a: cow, gorilla, zebra, deer, bear, turtle, and eagle.

Procedures

The researcher set up a video camera and the materials in front of the parent-child dyads on a table. The researcher invited them to play with the diorama and indicated she would be back in 20 minutes, leaving the camera running. The video tapes were transcribed. Analysis was conducted on both the transcripts and the video data for both verbal and non-verbal expression of eating relations. However the findings in this paper are only derived from the forms of eating relationships expressed in the talk.

Coding & Analysis

The data was coded along four dimensions including: kinds focused on; forms of relations between kinds in eating relationships, use of generics verses specifics; and presence of internal state ascription. The kinds focused on dimension and forms of relations code had subcodes. *Kinds focused on* refereed to the type of living and non-living things were talked about in eating relations. These codes included: animals, mammals, reptiles, insects, fish, birds, plants, and water. *Forms of eating relations* including the following five codes: properties of kinds (e.g. bears eat fish); food chains (e.g. bears eat fish and fish eat worms); food webs (e.g. bears eat fish and eagles eat fish); and feeding relations (e.g. mother eagles feed their babies). Each eating relationship was coded for whether it was in the form of generics (e.g. bears) or specifics (e.g. this bear). Finally, for each eating relationship talked about, the presence of interpretation of the internal state was coded for.

Results

Preliminary results (we will have a second coder to ensure reliability) reveal cross cultural differences across all dimensions. Each are reported.

1. *Kinds focused on.* A chi-square test of independence was used examine the relationship between cultural community and kinds focused on. The Native dyads were significantly more likely than the European American dyads to include eating relationships that included insects (X^2 (1)=23.6, p<.01), fish (X^2 (1)=4.98, p<.03), birds (X^2 (1)=6.22, p<.03), and plants (X^2 (1)=10.28, p<.01). There was no difference between cultural communities inclusion of animals, mammals, reptiles, and water.
2. *Forms of eating relations.* A chi-square test of independence was used examine the relationship between cultural community and forms of eating relations. The Native dyads were significantly more likely than the European American dyads to reflect forms of eating relationships in food chains (X^2 (1)=7.572, p<.01) , feeding relations (X^2 (1)=3.88, p<.05, and to have multiple forms intersecting (X^2 (1)=6.25, p<.03). There was no difference between cultural communities use of food webs and properties of kinds.
3. *Psychological distance via generics and specifics.* A chi-square test of independence was used examine the relationship between cultural community and use of generics and specifics. The Native dyads were significantly more likely than the European American dyads to use specifics (X^2 (1)=3.86, p<.05). There was no difference between cultural communities use of generics.
4. *Perspective taking via eating directions and internal states.* A chi-square test of independence was used examine the relationship between cultural community and perspective taking. The Native dyads were significantly more likely than the European American dyads to reasons from prey to predators (X^2 (1)=5.7, p<.03). They Native dyads were also far more likely to attend to the internal states of the focal kinds (X^2 (1)=11.6, p<.0001). There was no cross-cultural difference in reasoning from predators to prey.

Discussion

The significant difference in children and parent talk found in these studies suggests that Native children and parents are far more likely to engage in thinking about eating relations with a wider range of kinds, with a variety of forms of relationships between those kinds. These various forms may have implications for how more complex reasoning patterns emerge because they are routinely engaging in a variety of cognitive patterns as compared to non-Native dyads. Further these results demonstrate that the Native dyads are more likely to engage in psychological close reasoning and perspective taking. We suggest that reasoning from predators to prey is a form of perspective taking in explore eating relationships rather than always reasoning about eating relationship from predators to prey. Further attending to the internal states of the focal kinds suggest that Native dyads are thinking about the context of the eating relations event from multiple perspectives. This spontaneous difference in parent-child talk would have significant long-term impacts on children's cognitive development.

Nat's Maps: A Case Study in Climate Change Cognition

Megan McGinnity

Climate change is an example of a complex nested system that is causing profound and rapid changes in every natural system that we depend upon (IPCC, 2007). As a result the Next Generation Science Standards (NGSS Lead States, 2013) call for teaching global climate change. At the same time, an ongoing challenge in education is to develop an accurate understanding of (and to teach) complex systems (Plate, 2010). Research indicates that students and teachers don't understand complex systems very well and pedagogical norms have not yet been established. (NRC, 2012, Plate, 2010)

Simplistic understandings lead to simplistic, linear and inadequate solutions (Venville, Rennie, & Wallace, 2012) and linear causal patterns do not reflect the phenomena of causality in systems (Lagnado et al., 2007; White, 1992). When aspects of the Earth's climate system are taught according to a high school curriculum, they are usually parsed into separate, specialized disciplines, such as biology or chemistry. This approach can be problematic (NRC, 2012; Venville, Rennie, & Wallace, 2012) in that does not portray these disciplines as a series of steps in a greater whole and can go in the opposite direction by mis-rendering a complex problem as simple and misleading students towards a simple solution.

Concept maps have been used as a tool to explore students' understanding of complex systems and climate change (Rye & Rubba, 2002), but they do not address the issue of causality. Lagnado et al (2007) found that most people represent causal knowledge qualitatively, in a series of linked events, while White (1992) described causal hierarchies in which participants described natural processes as one-directional, with humans being at the top of the chain. This study sought to investigate how environmental educators understand and reason about climate change and to determine what the participants learned in this professional development. A case study was used to investigate the conceptual structures and dynamics of one educator's understanding and how they changed over the course of the professional development period. The participants in this study were environmental educators undergoing a professional development in climate change. "Nat" was an experienced environmental educator who characterized himself as 'not comfortable with science'.

This study drew upon traditional methods in cognitive science where participants draw their own causal maps to make their reasoning visible (Kearney and Kaplan, 1997). Plate (2010) proposed a program called Cognitive Mapping Assessment of Systems Thinking (CMAST) that focuses on the creation of web-like causal structures. These causal maps represent the flow of case and effect, communicating an individual's metacognitive knowledge and can make their conceptual inferences and connections more explicit (Plate, 2010). The card task used in this study was derived from Plate's CMAST methods and adapted to allow for relationships where participants suspected causality between two factors but were unable to specify the nature.

The participants were given a set of cards that contained concepts affiliated with climate change. They selected the term needed to describe climate change to a person unfamiliar with the topic. Once the cards were selected, the participants divided them into groups and named each grouping. All the selected cards were then stacked together and laid out one at a time on a large sheet of paper, drawing the relationship, if any, between the two cards. After the relationship between all the cards on the sheet were established, the next card was added and the process repeated. By the end of the exercise, a web of causal influence-relationships between all of the items had been mapped out. Tasks were administered before and after the professional development period, yielding pre- and post- maps.

Two types of analysis were employed in looking at the maps: structural & dynamic. Structural analysis focused on the structures within the map while dynamic analysis was concerned with Nat's reasoning in drawing the relationships between the concepts. Conceptual nodes (cards / terms) & conceptual links (arrows). Plate, (2010) used 'link density' to determine how many concepts were being incorporated into a map. As a score, it is the ratio of links to nodes in a given system map. However, one shortcoming of link density is that it does not measure the complexity of branching and loops in a map. Branching in the occurrence of more than one arrow to/from a concept and indicates multiple causes and effects in reasoning about a particular concept.

Loops are a return to an earlier concept in a chain of reasoning and represent reciprocal relationships. Map complexity can be better quantified by using a Web-like Causality Index (WCI), a score calculated by adding the percentage of nodes with more than one cause to the percentage of nodes with more than one effect.

Nat's pre-map had a link density of 3.30 with eleven loops and his post-map had a link density of 2.09 with two loops. The drop in link density scores and loops could be seen as a simpler causal post-map, but this may also be a sign of increasing expertise as Nat became able to discern and select the most salient concepts (Bransford, 2000). This is further supported by the pre- and post- WCI scores of 0.42 and 0.49 respectively, indicating a greater complexity in his post- map.

The dynamic analysis was used to develop some measure of Nat's ascription of causal impact to a given concept in the map. When Nat grouped and labeled his selected card terms, one group was labeled "Human-caused things/ Things that humans are doing". That group held four terms (deforestation, human consumption, industrialization, and greenhouse effect). These terms, along with the term "fossil fuels" were designated as 'human-determined', meaning that they are directly related to human actions or are implicated heavily in human actions that affect the climate. In looking at the relationships between the concepts, two key questions were determining when were they the sources or recipients of causation and how often they were implicated.

A causal "agency" measure was created to assign a score to all the node terms in the causal map. In this case, the word 'agency' is the amount of influence a noded term has on other nodes. When an arrow originated from a node, that term was considered to have a source arrow. If the node was the terminus of an arrow, that term was considered to have an influencing arrow. Each term was then assigned a Causal Agency Index score, where its source arrow score was subtracted from its influencing arrow score. Overall, human-influenced terms decreased in causal agency while natural terms rose in agency from pre- to post-.

The frequency measure was determined by the number of times the term (node) was connected to a second term. The results are displayed in Figure 2. The human-determined terms on the rose are clustered at the bottom. There is a noticeable pre- to post- shift in the prominence of the human-determined terms while some natural terms and processes gain in frequency. In short, this figure demonstrates an overall decline in the activity of the human-determined terms and an increase in terms associated with natural processes.

In summary, Nat's thinking about climate change & complex systems changed from the pre- to post-measures. Structural analysis suggests increased expertise and greater complexity in his thinking while dynamic analysis indicates a shift away from human-determined terms in both ascription of agency and usage in the maps. The concepts of agency and the role of humans have great implications for our ability to teach complex natural systems and can better inform further study in developing curricula that help us to understand and teach complex natural systems.

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