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Creating a complex learning environment for the mediation of knowledge construction in diverse educational settings

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The role of complex learning environments in the mediation of knowledge construction is examined. The research incorporated activity theory and recent trends in complexity theory and chaos theory. Our main aim was to describe how an understanding of cognition as a complex system can facilitate the challenge of addressing diversity by spawning cognitive interventions that can tolerate and address complexity and non-linearity in thinking and problem-solving. A design experiment format was used for data collection as design experiments lend themselves to the study of cognition in natural and complex settings. Results suggested complex learning environments may be particularly well-suited to the mediation of knowledge acquisition skills, metacognitive awareness, and critical thinking skills.

Introduction

One of the greatest challenges facing schools is teachers' ability and commitment to address cultural and linguistic diversity (Ball, 2000). Diversity presents special challenges to educators because the variety of cognitive, social, and emotional styles make stereotyped and uniform treatment that ignore the complexity of children' lives, impossible.

The recognition of learning as a complex activity has received much attention in studies of self-regulated learning (SRL), described as children's ability and propensity to be active participants in their own learning (Patrick & Middleton, 2002). Generally, research on SRL has pointed to the importance of factors such as the nature of learning tasks, instructional contexts, and interaction.

Patrick and Middleton (2002) suggest that qualitative research methods are particularly well-suited for the study of SRL because they involve rich, holistic descriptions, they emphasise the social settings in which phenomena are embedded and they are oriented towards revealing complexity. Stadler, Vetter, Haynes and Kruse (1996) claim that, to study the full complexity and dynamics of complex systems, experimental methods must be used that accommodate the complexity of the system and that encourage the system to follow its inner dynamics freely.

This article describes the use of a poster in a qualitative design experiment format. The research was based on the assumption that traditional approaches to cognitive intervention[1] often do not address adequately the complex and multi-dimensional nature of cognition. Our main aim was to describe how complex learning environments can facilitate an understanding of the complexity of cognition. Understanding its complexity can help teachers to address diversity by spawning cognitive interventions that tolerate and address the complex business of thinking.

A mediational approach to knowledge construction

Educators in South Africa are expected to show foundational, practical and reflective competence in a variety of roles ranging from leader, administrator and manager through learning mediator and scholar, to researcher and lifelong learner (RSA, 2000).

In terms of educators' role as mediators of learning, the Norms and Standards for Educators (RSA, 2000) states that

> the educator will mediate learning in a manner which is sensitive to the diverse needs of learners, including those with barriers to learning; construct learning environments that are appropriately contextualised and inspirational; communicate effectively showing recognition of and respect for the differences of others (RSA, 2000:13).

Teachers in South Africa are required to be systematic in their development of children's cognitive abilities and they are expected to engage with children in a manner that will help children appreciate the complexities of life problems so that, in time, they can learn skills to address problems actively and independently.

Mason (2000) argues that teachers should be mediators of knowledge and act as socio-cultural critics, which entails that they, as mediators of knowledge, are "always aware of the learner's level of understanding and development so that learning can be appropriately targeted" (Mason, 2000:347), and also states that teachers should be "actively mediating between what is known and what is not known" (Mason, 2000:348).

A mediational approach emphasises learning as a social process. In South Africa, social interdependence is an important concept which characterises the philosophy of *Ubuntu* (Goduka, 1999). The philosophy of *Ubuntu* is relevant to education in South Africa because it promotes an interdependent view of the self that emphasises the social construction of knowledge, which in turn emphasises the importance of parents, peers, teachers and the larger community in the cognitive socialisation of the child (Gauvain, 2001). African culture has traditionally attached greater value to collective responsibility, empathy (Goduka, 1999), and social association (Onyewadume, 2000) in learning. The role of culture in knowledge construction is important, because cultures play a significant role in arranging the occurrence or non-occurrence of events, controlling the frequency and level of complexity of these events, and controlling the patterning of events that give rise to cultural taxonomies (Ceci & Nightingale, 1990).

Neither the Norms and Standards for Educators (RSA, 2000) nor Mason (2000) offers any specific suggestions about how to create complex learning environments which can facilitate knowledge mediation, or about the mechanisms by which knowledge construction is mediated. We will try to answer these two questions by examining the theoretical principles underpinning complex learning environments and how they can be created, and by taking a deeper look at the mechanisms of the mediation of knowledge construction.

Theoretical framework

The theoretical framework that informs this article is based on chaos theory. Chaos theory has been called the new science (Lorenz, 1993), the new paradigm from the physical sciences (Masterpasqua & Perna, 1997), and the science of change (Briggs & Peat, 2000). Chaos theory describes how change takes place in complex systems. We would argue that human cognition can indeed be viewed as a complex system, and that part of the reason why cognitive intervention is not always effective, may well be because this fact is not taken into account.

Cilliers (1998) observes that, for the human mind and cognition to be considered a complex system, it must meet specific requirements. Cilliers (1998) points out that complex systems are open systems which interact with their environment and can be modified by their environment. Complex systems are self-organising and their developmental trajectories are determined by countless interactions between the system and its environment. They typically operate under conditions far from equilibrium (Cilliers, 1998), called the maximum degrees of freedom of the system by Briggs and Peat (2000). Masterpasqua (1997:37) claims the concept of chaos indicates, in psychological terms, "a state of maximum readiness for an emerging reorganized self-system".

Complex systems science resonates strongly with the work of the Russian psychologist, Vygotsky (1962; 1978) who is well-known for his work on the development of higher mental processes in social and cultural contexts. It is particularly Vygotsky's (1978) position on the Zone of Proximal Development (ZPD) that reflects the notion of chaos and complexity in cognition well. According to Vygotsky, the ZPD refers to those psychological functions which have not fully matured, but are in the process of reaching maturity. We propose that the ZPD can be conceptualised in terms of chaos theory as a state of maximum readiness which enables the emergence of higher levels of self-organisation through the mediation of a capable mediator. In doing so, we recognize the principle of self-organisation, which is so crucial to a definition of a complex system but is not explicitly addressed in Vygotsky's theory, as a critical aspect in cognitive growth.

Complex systems consist of a large number of elements that interact with each other on physical as well as relational levels (Cilliers, 1998). Individual elements of the system are ignorant of the behaviour of the system as a whole, so that control in the system is not central, but arises out of the interplay of the agents (Waldrop, 1992 in Masterpasqua, 1997). Complex systems show rich interactions among their elements, with each element influencing, and being influenced by, a number of other elements. This characteristic makes it critical to study complex systems as they occur naturally (Kellert, 1993 in Perna & Masterpasqua, 1997).

Complex systems also consist of non-linear interactions. Non-linearity refers to the system's sensitive dependence on initial conditions (Lorenz, 1993), which means that a relatively small change can lead to the system achieving states that differ significantly. Furthermore, complex systems show interactions among elements that typically have a short range in the sense that they inform and transform their immediate environment, but not the behaviour of the system as a whole. Complex systems contain feedback loops in their interactions that allow the effects of any element to feed back into the system. Briggs and Peat (2000) distinguish between positive feedback loops, that amplify a particular effect, and negative feedback loops that diminish some effects.

Whether the mind is represented mathematically (Goertzel, 1993), or metaphorically (Perna & Masterpasqua, 1997), there can be little doubt that cognition is indeed exceedingly complex. The mind is an open system which can modify and be modified by its environment, whilst the richness and complexity of the electrical and chemical interactions that produce human consciousness are well-known. Certainly, the sensitive dependence on initial conditions, which is a generally accepted definition for chaos and complexity (Lorenz, 1993; Cilliers, 1998), is quite evident in the simple observation that two individuals can come to completely different conclusions about a problem under conditions that appear to be the same, but may differ significantly on some minuscule aspect. Therefore the notion of chaos acquires a very different meaning in the context of chaos theory. Chaos does not refer to lack of structure or order, but acknowledges that the dynamics of chaotic systems actually do have an internal order and pattern to their functioning.

Traditionally, theories of cognition have focused on reducing chaos and complexity in order to discover the structure of cognition. We propose however that the contrary is desirable, and so we believe that cognitive intervention must embrace the complexity and unpredictability of cognition, rather than reduce and control it. We think that a mediational approach to knowledge construction that takes advantage of the complexity of the learning environment is capable of doing just that.

Given the importance of social interaction in cognitive development, it would be reasonable to assume that social interaction can act as a powerful modulator in the evolutionary path of many cognitive processes. Social interaction is a multi-dimensional concept and it can act as a mechanism for cognitive change in a variety of ways (Gauvain, 2001). The primary cultural tool used in informal social interactions, as well as formal educational settings, is language. The language of social interaction may be just as important in the development of cognitive processes as social interaction. Language is the primary psychological tool through which a society mediates cognition and emotion, and can be considered a complex system in its own right (Cilliers, 1998). The mediation of knowledge construction demands attention simultaneously to cognitive, emotional and linguistic aspects of social activity, and also special consideration of the mechanisms by which they combine to impact upon the evolution of cognition.

The sociocultural context of cognitive development is currently well acknowledged (Merryfield, 2000; Watkins, 2000), but the mechanisms by which social, emotional and linguistic elements give rise to particular patterns of cognition remain largely unexplored. Not that this aspect of cognitive development has not intrigued researchers over the years. Vygotsky's (1978) ZPD is certainly one attempt at an explanation of a cognitive growth mechanism, and Feuerstein's (1980) theory of mediated learning experience — largely based on Vygotsky's ZPD — is also an attempt at refining how mediation can act as a mechanism for cognitive growth. The problem with both these theories, however, is that they do not explain exactly what aspects of mediation are responsible for cognitive change and by which mechanisms it occurs.

Research approach

Qualitative research accommodates and embraces many epistemological traditions such as positivism, constructivism, interpretivism, critical theory and feminism (Denzin & Lincoln, 2000). For this study, a qualitative research design with a modernist postpositivist approach to data collection and analysis was chosen. Design experiments were used for systematic eliciting of data as opposed to the creation of free-flowing narratives characteristic of interpretivist approaches to qualitative research. The data sets created from the researcher's interaction with the group of learners were subjected to classical content analyses associated with a postpositivist approach to qualitative research to discover patterns of meaning in the data (Ryan & Bernard, 2000).

Design experiment

Rationale and format

Design experiments are frequently used in educational research to create complex contexts for the research of context-based mathematical problem-solving where the goal is to transform children into more active, strategic problem solvers (Verschaffel, De Corte, Lasure, Van Vaerenbergh, Bogaerts & Ratinckx, 1999). Design experiments have also been used to collect qualitative data on children's learning (Ahlberg, Anismaa, Dillon, 2005), children's reflection skills (Zuckerman, 2004) and comprehension strategies (De Corte, Verschaffel, Van de Ven, 2001).

In the present study, the aim of the design experiment was to create a learning environment that would enable the study of cognitive intervention as a complex phenomenon. This was achieved by utilising a poster designed to encourage active participation in the form of unstructured discussion (Figure 1).

The interactive nature of the poster was considered to be an important tool in the design of a complex learning environment. Design experiments help to overcome the theory-practice gap by focusing simultaneously on theory building and the innovation of practice (De Corte, 2001, Verschaffel *et al.*, 1999). The poster design is consistent with the view that complex phenomena should be studied in their natural settings by methods that allow them to reveal their true complexity (Lorenz, 1993). Using posters in group discussions would allow cognition to be studied as an open system that is in dynamic interaction with its environment (Cilliers, 1998) and to create an ambiguous problem-space which accommodates the disequilibrium needed for self-organisation (Masterpasqua & Perna, 1997). Consistent with our interpretation of complexity and chaos,[2] no conscious attempt was made to simplify the illustrations or to reduce the complexity of the context on account of the participants' age and developmental level.

Because the research focused on knowledge construction, and

School:		Grade:		Date:		Time:	

Researcher behaviours that promote understanding of learners' **knowledge structures**			Researcher behaviours that impede understanding of learners' **knowledge structures**
KS1+: The researcher interacts with learners by asking their opinions about what they are learning. Also includes statements which request personal background knowledge and experiences			**KS1-:** The researcher interacts with learners by giving instructions which learners must follow.
KS2+: The researcher asks open questions that require participation from learners in the form of an extended verbal response.			**KS2-:** The researcher asks mainly closed questions which require one-word responses
KS3+: The researcher probes the thinking behind learners' responses and uses them as a basis for further inquiry.			**KS3-:** The researcher accepts learners' responses without any further inquiry.
KS4+: The researcher models clear, analytical thinking, or requests learners to provide evidence for their statements.			**KS4-:** The researcher accepts vague, ambiguous statements from learners without requiring evidence for statements.
Researcher behaviours that promote the use of **cognitive skills** in learning			Researcher behaviours that impede the use of **cognitive skills** in learning
CS1+: The researcher encourages learners to explore tasks systematically, asks learners to think before they act, or wait while someone else is busy.			**CS1-:** The researcher allows learners to approach tasks in a disorganised fashion
CS2+: The researcher models the execution of tasks to her learners			**CS2-:** The researcher requires learners to do tasks without modeling their execution
CS3+: The researcher guides learners in their thinking and task executions without showing them the correct way immediately			**CS3-:** The researcher immediately supplies learners with the correct answer or method when they encounter difficulty
CS4+: The researcher points out behaviours that enhance or impede problem solving.			**CS4-:** The researcher does not provide information on behaviors that can enhance or impede problem solving.
Researcher behaviours that promote a positive **learning disposition**			Researcher behaviours that promote a negative **learning disposition**
LD1+: The researcher engages in positive interactions with learners, makes empathic statements to acknowledge and confirm learners' opinions and conveys a personal interest in the learners.			**LD1-:** The researcher engages in negative interactions with learners, does not acknowledge learners' contributions and shows no personal interest in the learners.
LD2+: The researcher engages learners in discussions and encourages learners to respond verbally.			**LD2-:** The researcher discourages discussions with learners in the classroom and accepts pre-verbal responses such as pointing, headshaking.
LD3+: The researcher accepts partially correct responses and provides positive feedback.			**LD3-:** The researcher rejects responses that are partially correct and dismisses/rejects them as incorrect.
LD4+: The researcher attributes success in learning to intrinsic factors (e.g. the efforts of the learner, hard work)			**LD4-:** The researcher attitributes success in learning to extrinsic factors (e.g. luck, easy work)
LD5+: The researcher encourages risk-taking and invites learners to take chances, encourages learners to use their home language.			**LD5-:** The researcher discourages risk-taking, prevents learners from taking chances, discourages learners from using their home language.

Figure 1 Mediational Behaviour Observation Scale

seeing that particular contexts can act to elicit certain strategies over others (Ceci & Nightingale, 1990), the theme of the poster was thought to be particularly suited to accommodating knowledge acquisition skills such as naming, classifying and categorising. However, since cognition is conceptualised in the research as a complex and open system, the poster was capable of simultaneously mediating a host of other cognitive processes such as attention and memory processes, metacognition, evaluative thinking and academic skills in the learning areas of literacy, numeracy and life skills.

Constructing the learning environment

Vosniadou, Ioannides, Dimitrakopoulou and Papademetriou (2001) state that there is considerable general agreement that learning environments should be designed to promote active learning and guide children towards self-regulated learning. This, Vosniadou *et al.* (2001) argue, can be done by requiring children to participate in projects, solve complex problems, and think about their own and others' ideas. Verschaffel *et al.* (1999) describe three pillars around which they design a powerful learning environment. The first pillar involves the design of carefully selected and open problems, the second pillar is about implementing powerful instructional techniques and the third constitutes the establishment of a classroom culture.

Instructional techniques

The instructional techniques used during the design experiment were influenced by theories of mediation in the cognitive intervention literature (Feuerstein *et al.*, 1980; Feuerstein *et al.*, 1991; Kozulin & Presseisen, 1995; Vygotsky, 1978), and were furthermore informed by the requirements in the South African Norms and Standards for Educators concerning the practical, foundational and reflexive competencies of teachers as mediators.

The mediational interaction of the researcher was conceptualised around three core areas, namely, mediation of knowledge structures (domain knowledge), cognitive skills (procedural knowledge), and disposition for critical thinking (conditional knowledge) (Boekaertz, 1997). In the context of the present study, the distinction that Mason

(2000) makes between facilitation and mediation is important, particularly in the South African context where many teachers implementing outcomes based education (OBE) view themselves as facilitators. Viewing the teacher as a facilitator of knowledge does not sufficiently address the interpretive function of mediation, "where the teacher is actively getting involved in getting her hands dirty with the messiness and unfinished business of pragmatic knowledge" (Mason, 2000:346).

Establishing a culture of learning

The design experiment was carried out by the researcher and all efforts were focused on the establishment of a culture of learning associated with positive learning dispositions in the group than on establishing a classroom culture. Behaviours such as providing children with positive feedback, recognising partially correct responses and promoting the notion of self-responsibility by encouraging the formation of an internal locus of control form an important aspect of the development of learning dispositions. Selikow (1999:8) notes that

> thinking critically involves exposing yourself, your ideas and views and knowing they are open to discussion and disagreement. Hence the importance of setting up a climate of mutual trust.

Selikow (1999) consequently advises that the development of learning materials should make room for dialogue and the shared creation of knowledge as well as encourage argument, self-evaluation and reflection. In constructing the learning environment, the researcher wanted to create an emotional climate that would encourage children to participate and take risks. Feeling some measure of positive attachment to the leader of a group (in this case the researcher) may also contribute to increasing motivation in learning.

Empirical study

Research design

The research was conducted in a multicultural, inner-city school with predominantly African children from Grades 1–3. In addition to the black South African children, two white South African children, a Bulgarian child, and children from other African countries also participated in the research, totalling 51 participants (Table 1). The language of learning and teaching (LOLT) for all children was English. The researcher is a white Afrikaans South African female.

The design experiment was preceded by three days of informal classroom observation in order to gain some experience of how knowledge construction was mediated in the classroom.

Table 1 Design experiment participants (n = 51)

Group	Day 1	Day 2	Day 3	Total (Grade)
Grade 1	4	5	5	14
Grade 2	6	8	6	20
Grade 3	4	6	7	17
Total (children)	14	19	18	51

Method

Different children participated in each of nine group sessions in the design experiment. The sessions were audio-recorded and transcribed, yielding nine data sets for analysis (Table 2).

In each group session, children were presented with the poster face-down and asked to guess what it might be. The poster was then turned the right way up and a period of free discussion was allowed. The group session generally involved activities targeted at the development of metacognitive awareness by requesting learners to search on the poster for certain objects (selective attention and impulse control), counting objects meeting certain requirements (planning and monitoring), and checking their results (self-evaluation). Children were also required to group animals according to certain principles (analytical skills such as comparing and contrasting, classification), provide evidence for their choices (reasoning skills), and give reasons for their opinions and beliefs (critical thinking).

Table 2 Data sets (DS)

Grades	Day 1	Day 2	Day 3
Grade 1	DS 1 (n = 4)	DS 4 (n = 5)	DS 7 (n = 5)
Grade 2	DS 2 (n = 6)	DS 5 (n = 8)	DS 8 (n = 6)
Grade 3	DS 3 (n = 4)	DS 6 (n = 6)	DS 9 (n = 7)

Promoting the use of children's home language as a means of developing a positive cultural and learning identity was actively pursued by requesting children to provide the names of animals and tell stories about animals in their home language. In these cases, at least one other child speaking the same language was present and it was the task of that child to listen closely and translate the story into English for the rest of the group. The issue of home language versus English as the language of instruction is a complex issue. Whilst it appears currently that many parents of black South African children are actively pursuing English instruction for their children for political, economic and educational reasons (De Klerk, 2002:11), this is simultaneously questioned by Heugh (2002:181) who cites evidence from a study conducted in 2000 that suggests that, while many parents want their children to learn English, they also want their mother-tongue to be maintained. Murray (2002:111) reports that learning and using children's home language in the learning situation contributes to a deepened understanding of children's identity and is important for the development of mutual empathy, compassion and respect.

A mediational approach to knowledge construction requires the mediator to encourage dialogue (Mason, 2000) and active participation from learners. It also requires the mediator to relinquish some control in terms of determining where the discussion leads. To examine the participation of the researcher, the number of speaking turns that the researcher had relative to the group of learners was analysed (Table 3). In most groups, the relationship between participation by the researcher and the learners was approximately 2:3.

The data were reduced and made accessible by coding the data sets with a preliminary list of codes, formulated according to the theoretical framework of the study and contained in the Mediational Behaviour Observation Scale (MBOS), which was specially created for the purpose of the study (Figure 1). On the basis of a literature review of mediatory behaviours associated with the development of cognitive skills and strategies, the positive codes on the MBOS were operationalised to reflect mediational behaviours considered to be consistent with the principle that effective thinking requires a learning environment in which sufficient complexity is needed to create a dynamic balance between chaos and order. By contrast, the negative codes were operationalised to reflect behaviours that create a learning environment devoid of complexity and in which self-organisation is not likely to occur. The classification of behaviours as promoting or impeding complexity and self-organisation is based on the (as yet untested) assumption that teacher behaviours that encourage participation and discussion are more likely to lead to promoting complexity and self-organisation in the learning situation.

Data processing and analysis were done with the software program *ATLAS/ti*, "a powerful workbench for the qualitative analysis of large bodies of textual, graphical and audio data" (Muhr, 1997) designed to accommodate various tasks associated with the analysis of data which cannot be performed by quantitative measures.

To achieve rigour in qualitative data, Northcutt and McCoy (2004) suggest the use of public and non-idiosyncratic data collection and analysis strategies that allows the same conclusions to be drawn from the data by different researchers and on different occasions. Coding consistency rates were calculated by comparing the consistency with which the data sets had been coded on two occasions.

Table 3 Participation of researcher and children on the design experiment

	Day 1		Day 2		Day 3	
	Researcher	Learner	Researcher	Learner	Researcher	Learner
Grade 1	193 / 39.5%	295 / 60.5%	188 / 42.9%	250 / 57.1%	181 / 43.3%	237 / 56.9%
Grade 2	145 / 37.2%	245 / 62.8%	189 / 39.8%	285 / 60.2%	157 / 42.7%	211 / 57.3%
Grade 3	215 / 34.4%	410 / 65.6%	210 / 41.7%	294 / 58.3%	207 / 43.2%	272 / 56.8%

Table 4 Re-coding consistency rates for DS 1 – DS 9

	Day 1			Day 2			Day 3		
	DS 1	DS 2	DS 3	DS 4	DS 5	DS 6	DS 7	DS 8	DS 9
Total number of utterances in DS	162	113	184	168	159	168	132	132	184
Number of utterances selected for inspection	79	56	62	78	83	73	69	63	82
Percentage of utterances selected for inspection (%)	48.76	49.55	33.69	46.42	52.20	43.45	52.27	47.72	44.56
Coding consistency (%)	71.51	74.46	70.40	67.13	74.44	64.64	74.42	66.47	68.68

Table 5 Frequencies of MBOS codes across all data subsets*

Code	Description	DS 1	DS 2	DS 3	DS 4	DS 5	DS 6	DS 7	DS 8	DS 9	Total
CS1+	Systematic exploration of tasks	30	36	51	10	38	30	29	31	44	299
CS2+	Modelling task execution	0	5	1	0	0	3	2	0	1	12
CS3+	Guidance in task execution	84	55	76	72	91	62	86	75	112	713
CS3–	Immediate supply of correct answer	0	0	0	2	3	2	1	0	0	8
CS4+	Enhancing / Impeding behaviours	3	0	7	2	4	1	1	3	6	27
KS1+	Opinion / prior knowledge / experiences	15	7	24	10	6	20	3	4	8	97
KS1–	Giving instructions only	7	10	12	12	13	13	9	9	7	92
KS2+	Open questions	95	49	78	112	83	75	51	59	88	250
KS2–	Closed questions	31	22	23	26	22	29	40	20	37	690
KS3+	Probing children' responses	48	7	15	25	15	17	24	19	23	193
KS3–	Accepting responses without inquiry	7	2	10	7	10	7	7	5	11	66
KS4+	Models analytical thinking	32	8	15	26	16	17	33	26	21	194
KS4–	Vague / ambiguous statement	0	0	8	0	0	0	0	1	0	9
LD1+	Positive interactions	27	24	41	27	30	24	26	28	27	254
LD1–	Negative interactions	0	0	0	0	0	0	0	0	2	2
LD2+	Engaging children in discussion	64	47	66	90	47	40	60	53	53	520
LD2–	Discouraging discussions	0	2	0	0	2	0	6	6	1	17
LD3+	Accepting partially correct responses	9	10	11	7	14	14	7	3	9	84
LD4+	Intrinsic factors in success	2	5	1	2	3	0	2	0	1	16
LD4–	Extrinsic factors in success	0	1	0	0	0	0	0	0	0	1
LD5+	Encouraging risk-taking	4	3	8	3	11	4	2	4	3	42
LD5–	Discouraging risk-taking	0	0	0	0	0	0	0	0	1	1

* MBOS codes that are not listed were not coded because they were judged to be absent in the interactions

Calculating the consistency with which data were coded on more than one occasion can help to increase confidence in conclusions based on the codings because the patterns of meaning that the researcher attaches to the data appear to be relatively stable over time.

Half of the researcher's utterances were selected systematically from each data set for inspection. The results are given in Table 4.

The consistency rate with which utterances were coded ranged from 64.64% (DS 6) to 74.46% (DS 2). The overall mean re-coding consistency was 70.23%. Also, considering that a total of 645 researcher utterances were recoded, each utterance unique in its wording, judged without taking context into consideration, and that any combination of 26 codes was possible, a mean consistency of 70.23% was regarded as satisfactory.

Data analysis

Table 5 shows the frequencies with which the researcher's utterances were coded across nine data sets in the design experiment. Codes not included in the table were not allocated on any of the data sets.

The mediator behaviours coded most frequently were Guidance in task execution (CS3+, 713 times), followed by Closed questions (KS2–, 690 times) and Engaging learners in discussion (LD2+, 520 times).

Considering the complexity of the learning environment and the choice of mediation as the primary instructional strategy, the high frequencies of guidance and engagement are certainly to be expected. Guidance as opposed to instruction is generally regarded as one of the hallmarks of a mediational approach, and engagement of the children in the task reflects the sociocultural dimension of cognition. What may be somewhat surprising, is the high frequency of Closed questions (KS2–, 690) in relation to a much lower frequency of Open questions (KS2+, 250). One might expect closed questions to reduce complexity in the learning environment and limit the potential for self-organisation. However, closed questions can be expected reasonably more often with young children who are still learning to organise their learning behaviour. Therefore, where young children are concerned, creating complexity in the learning environment for self-organisation

Table 6 Association of positive and negative codes

	CS1–	CS2–	CS3–	CS4–	KS1–	KS2–	KS3–	KS4–	LD1–	LD2–	LD3–	LD4–	LD5–	
CS1+	–	0	0	0	0	0	0	0	0	0	0	0	0	CS1–
CS2+	**12**	–	0	0	0	0	0	0	0	0	0	0	0	CS2–
CS3+	**241**	**12**	–	0	0	4	0	0	0	0	0	0	0	CS3–
CS4+	**17**	**0**	**24**	–	0	0	0	0	0	0	0	0	0	CS4–
KS1+	**6**	**1**	**39**	**0**	–	13	3	1	0	2	0	0	0	KS1–
KS2+	**40**	**1**	**147**	**4**	**56**	–	21	2	1	9	0	1	1	KS2–
KS3+	**21**	**0**	**165**	**4**	**13**	**62**	–	3	0	4	0	0	0	KS3–
KS4+	**17**	**0**	**149**	**0**	**13**	**72**	**86**	–	0	1	0	0	0	KS4–
LD1+	**45**	**2**	**89**	**8**	**6**	**24**	**17**	**28**	–	0	0	0	0	LD1–
LD2+	**69**	**1**	**284**	**4**	**70**	**203**	**95**	**96**	**58**	–	0	0	0	LD2–
LD3+	**9**	**1**	**52**	**1**	**14**	**26**	**19**	**14**	**7**	**31**	–	0	0	LD3–
LD4+	**5**	**0**	**7**	**1**	**0**	**5**	**1**	**1**	**11**	**5**	**0**	–	0	LD4–
LD5+	**7**	**0**	**8**	**0**	**2**	**3**	**1**	**0**	**11**	**26**	**0**	**0**	–	LD5–
	CS1+	CS2+	CS3+	CS4+	KS1+	KS2+	KS3+	KS4+	LD1+	LD2+	LD3+	LD4+	LD5+	

Bold: Association among positive codes
Normal: Association among negative codes

to occur will depend on the balanced use of closed questions to structure the learning experience while still using open questions to challenge learners cognitively. Accommodating chaos in the learning situation is not about creating an unpredictable situation in which children are challenged beyond their means. Rather, it is about creating safe and structured opportunities for uncertainty to help children to question and debate, rather than simply accept and memorise.

Other codes that were also used relatively frequently include Systematic exploration (CS1+, 299), Positive interactions (LD1+, 254), Analytical thinking (KS4+, 194) and Probing and enquiry (KS3+, 193). The high frequency of CS1+, KS4+ and KS3+ suggests frequent mediation of metacognition as well as analytical reasoning and classification. The high rate of Positive interactions (LD1+, 254) suggests that the researcher wanted to promote the formation of healthy and positive learning dispositions by creating solidarity with the children through the use of encouragement, acknowledgement of responses and empathy.

Negative codes are relatively limited, excepting for KS2– (690), KS1– (92), and KS3– (66). The more frequent use of positive codes suggests that a learning environment was created that was sufficiently complex to promote learning as a process of self-organisation.

To further analyse the allocation of codes, the number of times that codes had been allocated together was examined. Table 6 shows the association of positive and negative codes on the nine data subsets. Bear in mind that one code could be associated with more than one other code simultaneously, and so the frequencies recorded in Table 6 do not necessarily equal the total frequency with which one particular code was allocated as indicated in Table 5.

Guidance (CS3+) was positively associated with Engagement in discussion (LD2+, 284), Systematic exploration (CS1+, 241), Open questions (KS2+, 147) Discussion (LD2+, 203), Probing (KS3+, 165) Analytical thinking (KS4+, 149). Although the combinations which were formed with CS3+ may suggest that Guidance in task execution (CS3+) shares some characteristics with the other codes and is therefore possibly not a pure construct. The strong association between Guidance (CS3+) and Discussion (LD2+, 284) indicates that guiding children in their thinking and task execution through discussion was one of the primary mediational strategies in the group sessions. Figure 2 shows examples of utterances coded with both CS3+ and LD2+.

In 241 instances, the researcher *guided* children in their thinking by encouraging Systematic exploration (CS3+ and CS1+). This was done by requesting children to think before they acted, to wait their turn, or to tackle a problem by following certain steps. Figure 3 shows examples of researcher utterances coded with both CS3+ and CS1+.

In 165 instances, the researcher *guided* children in their thinking by *probing* their answers and using their responses to *mediate further enquiry* and problem-solving (CS3+ and KS3+), trying to make their reasoning explicit to the rest of the group. Figure 4 shows some examples of researcher utterances coded with CS3+ and KS3+.

Guidance (CS3+) was coded with Analytical thinking (KS4+) on the same utterance 149 times, indicating that the researcher guided children in their thinking by modelling analytical thinking and/or requesting them to explain their answers. These utterances frequently required children to attend to similarities and differences. Figure 5 shows some examples of researcher utterances coded with CS3+ and KS4+.

Guidance (CS3+) was associated with Open questions (KS2+, 147) when the researcher used open questions as a means of guiding children in their thinking. The questions had various functions, such as encouraging them to question one another's viewpoints or promoting the use of prediction as a problem-solving strategy. Figure 6 shows some examples of researcher utterances coded with CS3+ and KS2+.

From the association of KS2+ and LD2+ in 204 instances, Open questions also emerged as an important strategy in Engaging children in discussions. The relatively strong association of KS2+ with KS3+ (62 instances) and KS4+ (72 instances), further suggests that Open questions were readily used as a mediational strategy to probe children's answers and as a strategy to promote reasoning skills by requesting learners to provide evidence for their arguments.

It is not surprising that Table 6 shows very few associations among the negative codes, as most of the negative codes were rarely given (Table 5). Table 7 shows the association of the three highest frequency negative codes (KS2– 690; KS1– 92; KS3– 66) with positive codes.

Closed questions (KS2–) shows a number of strong associations with other codes, which is not surprising since KS2– is the code most often allocated (690 times) after CS3+ (713 times). In fact, KS2– and CS3+ were associated with each other in 338 instances. KS2– was also associated with LD2+ in 261 instances, and with CS1+ in 103 in-

Location in DS	Utterance
1:398-399	*How are we going to know if there are five? What did we do with the ants to count them? What did we do with the ants?*
3:685-686	*Okay, so where are you going to start if you want to count all the money?*
5:295-298	*It is! Why is it a bird? Why do we call it a bird? There are two other things that are important. Apart from the fact that a bird must be able to fly, there are two other things ...*

Figure 2 Researcher utterances coded with CS3+ and LD2+

Location in DS	Utterance
2:542-545	*Okay, I'm going to make a pattern on this board over there. I'm going to put them in a row, and I want you to tell me how to finish the pattern.*
3:382-384	*Do you think ir might help if you close one part and you only look here, and you count all the butterflies that you see on this side.*
5:265-266	*Okay, what did I ask you to do? Just a second, what did I ask you to do now after you put the bead on the bird?*

Figure 3 Researcher utterances coded with CS3+ and CS1+

Location in DS	Utterance
3:139	*Yes, do you know what kind of buck?*
4:95	*Yes, a long neck. Why are their necks so long, do you think?*
4:205	*Okay. Is a monkey smaller or bigger than a baboon?*

Figure 4 Researcher utterances coded with CS3+ and KS3+

Location in DS	Utterance
1:207-208	*Let's just look at the bee. This one looks like it has horns, but it actually is not horns. We call it something else.*
7:335-337	*That's right, Amos! Can you see the spots are different? The spots of the cheetah are black. The spots of the leopard look like there is a little yellow thing inside.*
8:358-359	*An insect always has ... listen to this: An insect always has three pairs of legs.*

Figure 5 Researcher utterances coded with CS3+ and KS4+

Location in DS	Utterance
9:134-136	*What do you think about Koki's answer? He's asking us if it isn't a zoo?*
9:595-596	*What will happen if we put the two leopards in the cage over here?*
9:629	*Why not? What did we say about the rules?*

Figure 6 Researcher utterances coded with CS3+ and KS2+

Table 7 Association of KS1–, KS2–, KS3– with positive codes

	CS1+	CS2+	CS3+	CS4+	KS1+	KS2+	KS3+	KS4+	LD1+	LD2+	LD3+	LD4+	LD5+
KS1–	38	2	44	3	1	3	0	2	12	15	2	0	3
KS2–	103	3	338	15	40	14	98	64	99	261	28	16	31
KS3–	0	0	6	1	0	5	0	4	18	14	0	1	0

stances. It appears, then, that Closed questions were frequently used to guide children in their thinking, to involve them in discussions, and to promote metacognitive awareness in the form of systematic exploration of tasks.

Instructions (KS1–) shows a relatively substantial association with Systematic exploration (CS1+, 38) and Guidance (CS3+, 44). Where KS1– was coded with CS1+ on the same utterance, it was because the researcher was giving children instructions designed to support them in the systematic exploration or execution of tasks, e.g. *No, do it like this so you can see it* (DS4:533),[3] or *Okay, you must now hand all your cards to the other learners* (DS6:629-630), or *Yes, listen to what Pindi says, don't grab* (DS9:159).

Instructions (KS1–) was associated with Guidance (CS3+) when the researcher guided learners in their task execution by giving them certain instructions, e.g. *Okay, do you have the number two? Let's change cards. Green goes to two, two goes to three, three goes to four, and four puts down* (DS2:227-229), or *Okay, I'm going to take your beads and I'm going to make a new pattern. I want you to look at the pattern and tell me ... how to finish it* (DS2:563-565).

KS3– shows some association with LD1+ (18) and LD2+ (14), the former when the researcher accepted children's responses without further enquiry and provided positive feedback, e.g. *Yes, you're right. You listened ... it's a crab* (DS1:243) or *Good, there's the frog. Show me where the snake is* (DS7:196). KS3– was associated with LD2+ when the researcher accepted children's responses without further enquiry and subsequently asked a question to engage them in further discussion, e.g. *Monkey. Okay, and there?* (DS4:298) or *It's big! What is this?* (DS4:257).

Discussion

The use of posters in this study to mediate knowledge construction in diverse educational settings was based on the assumptions that knowledge construction is a complex process best studied in a complex learning environment and that cognitive intervention should reflect the complex nature of thinking.

The overall higher frequency of positive codes on the MBOS suggests that the poster was used effectively to create a complex learning environment that can accommodate complexity and ambiguity. It appears that mediation during group discussions was useful in eliciting the cognitive skills considered necessary for self-regulated learning in a complex environment. The codes with the highest frequency, Guidance in task execution (CS3+) and Encouraging discussion (LD2+) suggest that when knowledge construction is mediated in a complex learning environment, it can promote a view of learning as a social phenomenon where children are required to reflect on their thinking, listen to the ideas of others and gradually assume control over their learning (Vosniadou *et al*., 2001). To assume control over their learning, children need to develop their ability to plan, monitor and control their thinking. These skills are indispensable to the development of self-regulated learning dispositions (Patrick & Middleton, 2002). The high frequency of Systematic exploration (CS1+) and the mediation of children's metacognitive awareness as represented by the combination of CS3+ and CS1+ not only suggest that these aspects were well addressed during the researcher's interaction with the children during mediation, but also lend support to Meyer and Turner's (2002) proposal that self-regulation is achieved through social interaction and should therefore be studied in a contextualised framework. In terms of practical application in the classroom, teachers should encourage children to use verbal strategies to direct and monitor their actions in the group as well as individually.

Whilst Meyer and Turner (2002) rightly acknowledge intersubjectivity as an important component in a sociocultural framework of self-regulation, we would add creative responsivity as an added dimension. Creative responsivity refers to a system's ability to respond creatively to unpredictable changes in the environment and this is what makes self-organisation possible. Creative responsivity requires a multi-directional flow of information between the system and its environment, as well as between various elements of a particular system. In this study, mediation was not conceptualised as a unidirectional process in which the mediator's contributions were designed to elicit a particular behaviour from children while remaining unaffected by children's contributions. The course of the mediation was as much affected by the contributions of the children, as were the interactions among the children in the group. Mediation emerged as an open, fluid and organic process in which unexpected contributions could change the course of the mediation significantly. In the classroom, teachers should be far more open to children's contributions by sometimes allowing children to direct the flow of the conversation.

Vosniadou *et al*. (2001) have suggested that learning environments should make it possible for children to express their internal representations and beliefs if they are to develop metacognitive awareness, even though such activities may be time-consuming. In this case, the combinations of CS3+ and KS3+, where the researcher's mediation was focused on probing children's thinking, and CS3+ and KS4+, where the researcher's mediation emphasised analytical thinking, provide good examples of how children can be encouraged to express their internal representations as well as learn to question the representations of others through debate and argument in a psychologically safe learning environment. Questioning children's thinking utilises an important principle in chaos theory, namely that of bifurcation. A bifurcation in a chaotic system occurs when the system destabilises temporarily, i.e. the system reaches disequilibrium and becomes chaotic, and then returns to a higher form of self-organisation. Bifurcations are necessary because without them, the system would be unable to self-organise, and would become closed off from its environment. Alternatively, a system in a perpetual state of chaos is also unproductive because the system fails to utilise information from the environment for learning. For example, probing children's thinking and requiring them to provide reasons for their answers can help them to realise potential gaps in their knowledge if they cannot provide satisfactory answers, or if their answers remain vague. The child's realisation of not-knowing creates a temporary state of disequilibrium, i.e. a bifurcation takes place, which is necessary for the child to realise that additional experience is needed and subsequently for new learning to occur. The more complex the learning environment, the more opportunities arise for bifurcations which enable learning as a process of self-organisation. Unfortunately, the trouble with learning environments that are predictable and closed off from the environment, is that they discourage the creative responsivity that is needed for children to respond to bifurcations. When learning in a predictable learning environment, children are accumulating experiences instead of responding to experiences and creating new ones.

However, this does not mean that children's learning experiences should provide destabilising experiences only. The relatively high frequency of three negative codes, namely Instructions (KS1–), Closed questions (KS2–) and No enquiry (KS3–) suggest that complex learning environments do not only require complexity, ambiguity and unpredictability but can also benefit from structure and predictability.

In these cases, the more frequent use of KS1–, KS2– and KS3– in association with the positive codes seems to reinforce the notion of dynamic balance between chaos and order for self-organisation to occur, especially concerning knowledge structures. The use of Instructions (KS1–) versus Seeking children's opinions (KS1+), and Probing children's answers (KS3+) versus Accepting answers without further enquiry (KS3–), all seem to be needed for a complex learning environment to bifurcate between chaotic states that lean more towards ambiguity and unpredictability, and ordered states that lean towards structure and predictability. This finding appears to support research that indicates structure and monitoring processes to be important features associated with academic progress (Long, 2000).

The study suffered from some limitations. Firstly, the exploratory nature of the research prevents any conclusions from being drawn about the long-term effectiveness of cognitive intervention approaches that utilise chaos and complexity. Secondly, while there appears to be some merit in using posters to mediate knowledge construction in formal contexts, it would do well to study chaos and complexity in more formal settings, such as regular classrooms. The design experiments were conceptualised and implemented by the researcher and not regular classroom teachers, which may raise questions about their implementability in classrooms. The design experiments involved small groups of learners where it was easier to influence emerging patterns of participation.

However, cognitive intervention need not be conducted in small groups only to be effective. Mediation that focuses on introducing complexity and chaos can probably be used effectively in whole-class instruction as well, especially if the teacher is skilled at providing a dynamic balance between structure and unpredictability. Moreover, children need to learn how to conduct themselves in discussions, i.e. they need to learn how to listen to others, how to respond, how to keep certain points in mind, how to order and structure their thinking and verbal responses and how to consider others' feelings. Facilitated discussion, i.e. in which the teacher plays a passive role, may not be as productive as mediated discussion, in which the active role of the teacher requires not only mediation of the content under discussion, but of the process of discussion itself. Group discussions require a significant amount of preparation and organisation and it is possible that discussions may fail because teachers do not always have the structuring and monitoring skills to conduct group discussions effectively (Long, 2000).

Ironically, it appears that classrooms today offer learning environments that are not particularly suited to the creation of complex learning environments for cognitive intervention. For example, Frederickson and Cline (2002) note that everyday classroom language is often dominated by the classroom teacher and takes the form of a stylised exchange of questions and answers which tend to reduce the average length of children's utterances by as much as two thirds. Long (2000) reports on studies showing that, when children in groups interact with the teacher, it is mainly to receive information and it generally does not require interaction with other group members. Also, teachers who feel overwhelmed by the demands of the curriculum may decide that an individual instructional approach would require less time to manage (Long, 2000).

Perhaps the question is therefore not whether cognitive intervention that requires accommodation of complexity and chaos can be adapted effectively to regular classrooms, but rather whether regular classrooms can adapt to the demands posed by cognitive intervention. Certainly, overcrowded classrooms and overwhelmed teachers make the kind of focused interaction that is proposed in this article, somewhat unlikely. Nevertheless, if the perception of the teacher as a facilitator can be changed to that of a mediator who actively selects, shapes and directs the learning experiences they expose children to, it may help to turn classrooms into more focused and responsive learning environments. To this end, some of the more important skills that teachers could use are the following: (i) guidance in task execution, (ii) active attempts to engage children in mediated group discussions, (iii) modelling the systematic exploration of tasks, (iv) providing ample opportunity for positive interactions with children, (v) modelling analytical thinking skills, (vi) further probing of children's responses to questions, and (vii) accepting rather than rejecting partially correct responses.

Mediation requires creative responsivity if children are to learn to adapt to the complex world they live in. Whilst this study suggests that teachers could play a central role in the development of children's responsiveness, a clearer understanding of how mediation affects children and, perhaps more importantly, why it affects various children differently and how it may be related to the development of learning dispositions still requires further research.

Notes

1. Cognitive intervention is defined as any formal attempt to stimulate or enhance childrens' cognitive functioning. It includes dedicated cognitive skills instruction programmes as well as thinking skills instruction in the classroom.
2. This statement appears to contradict the second law of thermodynamics which deals with the natural tendency of systems to move towards a state of entropy (chaos). However, thermodynamics deals with closed systems. The opposite tendency (self-organisation from chaos) is only possible in open systems (Tschacher & Scheier, 1997).
3. Data source 4, line 533.

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