


Learning affordances and participation enablers within a primary mathematics in-service community of practice

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This article investigates the participation enablers and learning affordances identified by teachers through participation within an in-service community of practice (CoP) of primary teachers called the Numeracy Inquiry Community of Leader Educators (NICLE) in the Eastern Cape. The article draws on three qualitative sources of data: the annual teacher questionnaires of 42 participating teachers, interview data from 8 of the 42 sampled teachers and reflective journal entries of these 8 teachers over the first 2 years of NICLE. All three data sets point to teachers foregrounding the affordances and enablers of NICLE participation across the fundamental elements of a CoP, namely domain, community and practice. We illuminate the way in which teachers' identification of learning affordances relates to these three structural features of a CoP. In concluding, we argue that explicit consideration of these structural elements, and their interrelationship in the design of in-service programmes, could enable clearer articulation of programme aspects and support reflection on the coherence between teacher feedback on these as programmes evolve.

Introduction and context

South African primary education, and mathematics education in particular, is struggling to overcome the lingering effects of its apartheid past. Inequality continues along racial lines with the 2003 Trends in International Mathematics and Science Study (TIMSS) indicating that South Africa was the lowest performing of 50 countries with the largest variation in scores (average scores of learners in African schools were almost half of that of historically white schools) (Reddy 2006). Results of the Annual National Assessments (ANAs), introduced by the Department of Basic Education (DBE) in 2011, indicate 11% as the 2014 national average performance for Grade 9 learners in Mathematics (DBE 2014). A range of complex factors contributes towards this continuing poor performance (see Fleisch 2008; Graven 2014).

Despite two decades of curriculum revision, the basic features of primary mathematics classrooms under apartheid continue. These include the dominance of oral discourse with limited reading and writing opportunities, classroom interaction patterns that privilege the collective (chorusing) and concrete working, and little evaluation and feedback of students' responses (Hoadley 2012). These features diverge from the 'intended' curriculum, which foregrounds the development of learners who are able to 'identify and solve problems and make decisions using critical and creative thinking' (DBE 2011:5). This points to largely ineffective forms of teacher development that have failed to support teachers in shifting practices. Ubiquitous departmentally organised 'workshops' focused on short-term information dissemination, with little opportunity for teacher engagement, have been largely ineffective for the past two decades (Taylor 2011). There is thus a need for new forms of professional development (Brodie & Borko 2016; Ndlovu 2014) that foreground more actively participating teachers in collaborative long-term partnerships (Graven 2012) and include early childhood teachers (Feza 2014). The recent national teacher development strategy promotes the establishment of professional teacher communities, 'based on the vision that learning is more effective when it takes place within a community of professionals' (DBE 2015:6).

It is against this background that the first author began the Numeracy Inquiry Community of Leader Educators (NICLE) as a long-term teacher development programme in the Eastern Cape as a key intervention of the South African Numeracy Chair Project (SANCP). It commenced in 2011 and ended in November 2015. The second author began his doctoral research investigating the nature of teacher learning within NICLE from the start of the programme.

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This article investigates the mathematical participation enablers and learning affordances identified by 42 teachers (Grade R–6) within their NICLE participation in the first 2 years of the programme. Our article draws on the 42 teachers' responses to end-year questionnaires and a smaller sample of 8 of these teachers' interviews and reflective journals. In this article, we illuminate the way in which teachers' stated take-up of learning affordances, and participation enablers within the community of practice (CoP), relates to the three structural features of a CoP outlined by Wenger, McDermott and Snyder (2002): domain, community and practice. Noting these features in teacher utterances furthermore led us to use these structural features for describing key aspects of NICLE, thereby enabling interrogation of coherence between programme intentions and teacher experiences. Wenger et al.'s (2002) fundamental elements provided an analytic and descriptive framework for the nature of teacher learning in terms of key participation enablers and affordances.

Theoretical perspective and key structural elements of a community of practice

The design of NICLE, and the research of teacher learning within it, was informed by Lave and Wenger's (1991) and Wenger's (1998) theoretical perspectives as well as by Jaworski's (2006) work on critical inquiry communities, hence the name Numeracy Inquiry Community of Leader Educators. Wenger's (1998) theory of learning in CoPs outlines four interrelated components: practice, meaning, identity and community. This work emerges from his earlier work with Lave (Lave & Wenger 1991) in which they argued that learning is located in the process of co-participation and increased access of learners to participation, through which learners develop changing ways of being and becoming. Within their view of learning, access to quality resources is prioritised. Therefore:

to become a full member of a CoP requires access to a wide range of ongoing activity, old-timers, and other members of the community; and to information, resources, and opportunities for participation. (p. 101)

Wenger (1998) defines a CoP as:

a living context that can give newcomers access to competence and also invite a personal experience of engagement by which to incorporate that competence into an identity of participation ... and a good context to explore radically new insights. (p. 214)

He argues that:

a history of mutual engagement around a joint enterprise is an ideal context for this kind of leading-edge learning, which requires a strong bond of communal competence along with a deep respect for the particularity of experience. When these conditions are in place, CoPs are a privileged locus for the creation of knowledge. (p. 214)

The NICLE focused on establishing partnerships with teachers where teaching competence develops through 'deep respect' for the teachers' particularity of experience and

drew on this as a critically important resource for engaging with the relevance of 'new insights' and research-informed resources for local contexts. The 2011 orientation document states that teachers, project staff and other key partners would:

form a partnership in which we are all co-learners. In this co-learning agreement we will all be participants working together, bringing different experiences and expertise to share in the community. (SANCP 2011:2–3)

It further states that teacher experiences were 'the foundational basis' from which to proceed' (SANCP 2011:2–3)

The fundamental structural elements of a CoP (domain, community and practice) and their indicators were used as a structuring device for analysis of teacher data on learning affordances and participation enablers. Here we unpack the ingredients of these three elements and discuss the meaning of resources and their use in the analysis.

The structural element of domain creates 'common ground [that] brings people together and guides their learning' (Wenger et al. 2002:31). It consists of 'hot topics', 'the best knowledge and skills' and 'key issues or problems that members commonly experience' (p. 32). Members of a CoP may share a profession or discipline. For NICLE, the domain is 'mathematics' as a primary school subject. Teacher comments relating to this domain are thus those that refer to key topics covered, 'best' mathematical knowledge and skills developed and the key issues or common problems (e.g. language challenges in multilingual classes) in teaching mathematics identified by the teachers, and engaged within NICLE.

The structural element of practice encompasses the body of shared knowledge, resources, 'latest advances in the field' and a set of 'socially defined ways of doing things' (p. 38) in a specific domain, which enables participants to learn and become practitioners in their craft. Wenger et al. (2002) also mention a range of tools, concepts, theories, models, symbols and documents which members share in practice. Teacher comments relating to practice are thus those that refer to use of NICLE resources in the practice of teaching mathematics which include physical mathematics learning resources provided in NICLE (e.g. dice), conceptual tools for teaching mathematics to develop conceptual understanding (e.g. number lines), watching classroom demonstrations and engaging with learning theories.

Wenger et al. (2002:34) define community as a 'group of people who interact, learn together, build relationships, and in the process develop a sense of belonging and mutual commitment'. Community members interact regularly to develop a shared understanding of their domain and an approach to their practice. An effective or strong community is characterised by relationships of mutual respect and trust, and offers a place of exploration where it is safe to speak the truth, share ideas, expose one's ignorance and ask hard questions. A community also consists of a 'field of experts' that recognises and validates innovations in a community.

Teacher comments relating to community are thus those that refer to interacting with fellow teachers, other NICLE members and invited 'experts' and building relationships among members. Furthermore, comments relating to developing a sense of belonging as a member of NICLE and developing mutually respectful trusting relationships in NICLE were considered to relate to community.

Describing Numeracy Inquiry Community of Leader Educators' structural elements

In 2011 and 2012 NICLE met every second week across the two-year period. This meant that 3–4 sessions were held per term across each school year. In total, 27 workshop sessions were held. Various local, national and international guest speakers and a number of NICLE teachers provided stimulus input and activities for workshops. On several occasions, NICLE teachers provided live classroom demonstrations of their teaching. All workshops followed a similar structure: presenters provided teachers with a stimulus for discussion in the form of presentation of ideas, followed by group work, discussion and activities. Resources for classroom use, based on the topics of discussion, were provided. In subsequent sessions, teachers provided feedback on their experiences of using these resources in their classrooms. In this section, we outline how NICLE was designed as a CoP and unpack specific aspects of the domain, practice and community elements that constituted the NICLE joint enterprise.

Key aspects of the intended Numeracy Inquiry Community of Leader Educators domain

The first author coordinated NICLE and presented about half the NICLE workshops over the two-year period, while the other half were presented by invited speakers who ran workshops on a range of topics in areas of their expertise. 'Number-sense' was foregrounded and presenters were chosen for their expertise in key topics supporting the development of number-sense. Examples of topics included using key conceptual resources, connecting concepts, developing efficient calculation strategies and mental fluency, and using language as a resource for learning. These topics constituted the NICLE domain providing 'common ground' and 'best knowledge'.

Key aspects of the intended Numeracy Inquiry Community of Leader Educators practice

The NICLE practice included the provision of a range of resources including session handouts (usually summarising key ideas or activities) and resources for use with learners in class. These resources captured in written or physical form some of the key aspects of the NICLE joint enterprise. The 'defined way' of engaging with these resources was through active engagement of all participants with them in NICLE sessions and in their own classrooms – then feeding back in NICLE sessions experiences of using these resources along with suggested adaptations. Key resources included physical

teaching resources provided, models and concepts shared (i.e. multiple representations for concepts/perspectives of learning, i.e. socio-constructivism) and related pedagogical practices (such as learner-centredness). Socio-constructivist views of learning became the shared and socially defined ways of how NICLE members interpreted effective mathematics teaching and learning.

Key aspects of the intended Numeracy Inquiry Community of Leader Educators community

The NICLE community was constituted by teachers, project members and invited partners who interacted and learnt together regularly. Induction into NICLE foregrounded mutual respect between members and acknowledgement that member contributions were a key resource for engagement. In the partnership of teachers, academics, researchers and teacher educators, the critical resources of classroom experiences, knowledge of learners and knowledge of the key challenges they faced were the basis for NICLE engagement. Active teacher participation was key to the NICLE joint enterprise. While university-based members brought research-informed resources and local, national and international networks of mathematics education experts to engage and share key resources with, NICLE teachers brought the critical experiences of using such resources in local contexts. Active participation was enabled by group discussions in every session and through strong working relationships among members. With time, the sharing of ideas by teachers increased and NICLE teachers themselves presented workshops including lesson demonstrations.

Research methodology

Our research of teacher learning adopted a qualitative, interpretive approach in which our knowledge and understanding emerge from our interpretation of teachers' lived experiences (Merriam 2001). This article combines data from end-year questionnaires for 42 NICLE teachers as gathered by the first author, with interview and reflective journal data from eight of these teachers, gathered by the second author as part of his doctoral study (Pausigere 2014). At the end of each year, all NICLE participants filled in a reflective questionnaire focused on their NICLE experiences. The questionnaires for 2011 and 2012 had 15 and 14 questions, respectively. Most questions remained similar across the years so that shifts in responses could be noted. In 2011 and 2012, 51 and 47 NICLE participants completed the questionnaires, respectively. We focus our article on the data of the 42 teachers who completed questionnaires for both years.

In reporting the questionnaire data, we have used teacher initials (adapted for anonymity), followed by the grade(s) taught (e.g. AM4) for each teacher. As 8 of these 42 teachers additionally participated in interviews and reflective journal writing, these teachers are referred to by pseudonyms so as to identify them within the larger sample. In this article, we analysed teacher responses to the questionnaire items: (1) Do you feel you are learning through your participation in

NICLE? If so, explain the nature of that learning; (2) Has anything changed in your mathematics teaching classroom practice as a result of your participation in NICLE? If so, explain.

For the eight interviewed teachers, we focused on the following questions:

- What do you think are some of the advantages of participating in NICLE? Some disadvantages?
- Which NICLE activities did you enjoy most? Why did you enjoy these activities?
- Which activities or materials did you use most in your mathematics classes? Why?
- Did NICLE support your own understanding of mathematics at all? If so, explain.
- Did NICLE support your teaching of mathematics at all? If so, explain.

A deductive data analysis approach was used to interpret data obtained from questionnaires, interviews and reflective journals. Recurring themes of learning affordances and participation enablers were identified. These themes covered the features of domain, practice and community.

Learning affordances and participation enablers

Borrowing from the work of Greeno (1998), we use the notion of affordances as:

qualities of systems that can support interactions for an individual to participate in. Affordances can be represented, using situation-theory notation, as if-then relations between types of situations, in which the antecedent involves resources in the environment and enabling characteristics of a person or group and the consequent type of activity that is possible whenever those environmental and personal properties are present. (p. 9)

Attunements to constraints become learning enablers in the sense that they 'include well-coordinated patterns of participating in social practices, including conversational and other interactional conventions of communities' (p. 9). Our article illuminates the way in which NICLE learning affordances and participation enablers expressed by teachers related to understanding specific numeracy domain concepts, appropriating numeracy teaching and learning practices into their classrooms, and a mutually supportive and respectful community.

For each structural feature, a summary table is provided that shows the number of teacher utterances in questionnaires and interviews across identified indicators. The first column of figures in each table (N_q) indicates the number of teachers (out of the 42) who referred to an indicator at least once across the 2011 and 2012 questionnaires. The second column (f) refers to the frequency of utterances of each indicator. Similarly, the third column (N_i) indicates the number of teachers, out of the eight interviewed teachers, who referred to an indicator at least once across the interviews. The final

column indicates the frequency of utterances in interviews. These tables are followed by qualitative analysis of the nature of these teacher responses. Questionnaire (Q) and interview (I) comments are included to allow teacher data to 'speak for itself'. The discussion is structured by Wenger et al.'s (2002) three elements and subindicators outlined earlier.

Domain-related affordances

Table 1 shows the frequency and distribution of domain-related utterances across various categories. All but three teachers referred to domain-related affordances in their questionnaires for 2011 or 2012. These 39 teachers contributed 140 domain-related comments across the two years. Just under one-third related to key themes; just under two-thirds related to 'hot topics' and the remaining 6% related to mathematical language in multilingual classrooms. In interviews, all eight teachers referred to domain-related affordances with a total of 36 comments over the two interviews. One-third of these related to themes, half to hot topics and one-sixth to language as a common issue.

Themes

Three key themes emerged from teacher responses when explaining their learning: teaching for number-sense and sense-making (11/42 teachers; 2/8 interviewees), developing problem-solving strategies (11/42; 4/8) and developing computational fluency, particularly through the use of games (12/42; 4/8). These cohere well with the NICLE domain design features discussed above. Within each of these themes, most comments related to how engagement in these NICLE sessions enabled teachers to teach these aspects more effectively in classes. In addition, teachers noted the way in which NICLE enabled them to develop their own number-sense and problem-solving skills. A sample of typical teacher comments related to number sense and problem solving is presented below:

Now I tend to think and do things differently than I used to do, and there are a lot of things especially with the number sense, that I have a clear understanding now. (Edna, I, Nov 2012)

[I learnt] new concepts, knowing how to solve problems ... and also questions that you may ask when you are dealing with [word] sums. (Pamela, I, Nov 2011)

Word sums can be classified using [the steps] Read ... Understand ... Choose the correct operation ... Solve ... Answers ... Check your answer by using the inverse operation. This session was very

TABLE 1: Utterances of Numeracy Inquiry Community of Leader Educators' domain-related affordances.

		Domain			
Indicator		$N_q = 42$	f	$N_i = 8$	f
Key emerging themes	Fluency progression	12	13	4	4
	Problem-solving	11	15	4	5
	Number sense	11	12	2	3
Hot topics	Mental mathematics	22	47	2	3
	Place value	16	17	2	3
	Zero	7	10	5	8
	Bar model	7	9	3	3
	Fractions	7	9	1	1
Common experiences	Language	6	8	3	6

interesting especially when I've tried to implement these steps with my learners, it was a success. (Pamela, Journal, Sep 2012)

Pamela's journal comments reflect her perceived success at using the shared problem-solving approach presented by a guest speaker in her classroom. The problem-solving steps noted by Pamela for 'word sums' are one of many heuristics available for mathematics problem solving. Research has shown that explicitly teaching such heuristics supports students' problem-solving performance (e.g. Schoenfeld 1979).

Hot topics

A wide range of topics were noted by teachers in relation to what they had learnt. As expected, these linked closely with topics covered in NICLE.

The most noted topic in the questionnaires was mental mathematics (47 comments by 22 teachers). Developing mental mathematics skills with learners was included as a topic in three non-consecutive NICLE sessions. The second most noted topic was 'place value'. While this topic had an entire session dedicated to its teaching, it was also included in several other sessions, one of these being a demonstration by one of the NICLE teachers of her work with a group of Grade 3 learners using individual sets of place value cards. The topics 'zero' and 'the bar model for problem solving' were each topics of a single NICLE session. The topic 'fractions' was extensively covered in three consecutive sessions and although not noted by teachers widely, they commented extensively on their use of the laminated fraction chart resource, as enabling student conceptual understanding.

Similar to the utterances relating to themes, 'topic' comments related to both the teachers' own learning and learning about how to teach the topic. In addition, several teachers noted awareness of the importance of focusing attention on key topics or what is also referred to as 'big ideas' in mathematics teaching (e.g. Siemon, Bleckly & Neal 2012). An example of a teacher comment in relation to focusing on key 'topics' is given below:

I have realised that the learners continuously need exercise building and decomposing numbers. ... The learners' ideas of place value need more attention than I normally anticipate. The Flard (place value) cards were readily available and easy to use in whole class teaching and learning. When the learners saw the parts of the whole number and how it is built from a single number it became clear – more so for slow/low-ability learners. (Robert, Journal, undated 2012)

Siemon et al. (2012) note understanding the part-part-whole structure of number and place value (base-10 system) as the two big ideas in relation to number that students must develop in the Foundation Phase.

Common issues

While language policies in schools allow for learners to receive mother tongue instruction in primary schools, the

majority of schools switch to English as the medium of instruction from Grade 4, resulting in 72.2% of Grade 4 children entering English-medium classrooms being non-native speakers of English (Robertson & Graven 2015). All NICLE Intermediate Phase teachers (i.e. Grades 4–6) as well as many of the Foundation Phase teachers (i.e. Grades 1–3) taught mathematics in English or Afrikaans. This was done despite the fact that many of their learners were first language isiXhosa-speakers. Most NICLE teachers therefore experienced the common challenge of teaching mathematics in a language that many learners were not yet fluent in.

Two NICLE sessions dealt explicitly with addressing such language challenges. The importance of reconceptualising language as a resource (Planas & Setati-Phakeng 2014) was emphasised through promoting use of multiple languages and code switching in teaching and learning mathematics (Setati 1998). However, only 6 of the 42 teachers in the questionnaires, and 3 of the 8 interviewed teachers, commented on the language sessions. This could imply that the promoted practices, such as code-switching, were either already being used by teachers or were not taken up. In some schools, we learnt that teachers are discouraged from using languages other than the official language of instruction.

Teacher utterances included comments on how sessions provided support for using language more effectively in mathematics teaching, as well as how they now understood the importance of paying explicit attention to language in mathematics teaching as is promoted in local and international literature (e.g. Moschkovich 1999; Setati 1998). The following excerpts from Calvin, a Grade 4–7 teacher, illustrate this:

I must compliment [*the guest speaker*] with her talk on multilingualism. She really opened my eyes. It was so relevant to my situation at my school. ... The usage of maths language was very insightful. (Calvin, Q, 2012)

I want a copy of this [*bilingual mathematics dictionary*] to give to all the teachers and I'm sure we're going to use this next year because it will make life easier. Where I have a term in English, then I can go in here and get the Xhosa meaning of the word and then I can give it to the kids. (Calvin, I, Nov 2012)

Language is a problem in my case as learners are isiXhosa speaking and I am Afrikaans speaking. The medium of instruction is however English. I must make sure that I have more resources explaining things in English and Xhosa. (Calvin, Journal, Sep 2012)

The above analysis shows teachers' identification of their learning in relation to domain-related themes, topics and common issues and how teaching problem-solving heuristics, focusing on 'big ideas' and the issue of language (as promoted by the literature referred to above and engaged with in NICLE) supported their mathematics teaching practices.

Next, we interrogate the nature of primary mathematics teaching and the learning practice affordances reported as enabling primary mathematics teacher learning within the NICLE CoP.

Practice-related affordances

Practice-related affordance utterances had high frequencies in both questionnaires and interviews when compared to the frequencies of domain-related affordances. Comments fell into four categories aligned with Wenger et al.'s (2002) indicators for the fundamental elements of practice (see Table 2).

Physical resources

The majority of NICLE sessions provided sets of physical teaching resources for use in class (e.g. dice, flashcards, wooden cubes and learner workbooks). Teacher comments pointed to valuing these resources and, in particular, how these enabled using session ideas in their classrooms. At the end of the first year, analysis of a sample of learner books across schools pointed to low levels of written learner activity (Graven 2016a). It was thus considered important that opportunities should be created for learners to do more written mathematics, to work independently at their own pace and to develop fluency through practice. The 2012 'homework drive' provided teachers sets of learner workbooks as a take-home resource (see Graven 2016b).

Thirty-three teachers wrote in questionnaires about how playing NICLE card- and dice-related games enhanced their teaching. Many noted that they developed learner fluency, especially mental fluency, in the four basic operations. For example, Robert explained:

Usually I use the dice and they do multiplication of two digits, and you expand it to three digits, playing around and having a grid where they have to complete by adding those numbers. ... So I know the learners really enjoyed it. (Robert, I, Nov 2012)

Like Robert, many teachers (five of the eight interviewed teachers and four in questionnaires) said that dice and card games provided playful learning possibilities, which made numeracy learning interesting and enjoyable. For example:

I used the boxes full of resources very often especially the cards and dices for playing mathematical games and the learners enjoy it very much. (AM4, Q, 2012)

Seven teachers in interviews and 23 in the questionnaires reported using the NICLE physical resources in their mathematics classes. In particular, the homework books were highlighted as being useful and teachers explained that they, and their learners, 'enjoyed' using these. For example, Melania emphasised her and her learners' enjoyment in using these books:

Those [*workbooks*] were fantastic because um it was so nice to have something you know. Otherwise the children go home, they don't always (pause) their parents can't assist them. And you know one doesn't have the resources. We haven't got workbooks. We're not allowed to photostat because it costs a lot of money. So it's very difficult to get things to hand out to the children. They can learn things, but if they've got something to write down it's that much more meaningful. Those homework things were fantastic ... The children loved them. In fact, when they came they wanted to finish the whole booklet in one day. (Melania, I, Nov 2012)

Lave and Wenger (1991) and Wenger et al. (2002) argue that a CoP's shared resources, such as 'concrete objects', 'documents', 'manuals' and 'books', embody and enhance participants' understanding of a community's knowledge, its practices and its meanings. In relation to instructional approaches, many have argued that mathematics teachers' CoP resources are powerful in enabling teacher learning as they give teachers access to and emulate mathematics teaching practices (e.g. Silver 2009). Thus, physical resources (such as playing cards and dice) and printed resources (such as homework books) have embedded in them mathematical representations, structures and meanings which teachers use to enhance their instructional practices in various ways.

Conceptual resources, models and tools

Conceptual resources, models and tools are fundamental mathematics teaching resources that are commonly and universally used in practice to represent specific numeracy concepts. The seminal work by Ball, Thames and Phelps (2008) distinguishes *common* mathematical content knowledge needed by all people from the *specialised* content knowledge for teaching, which includes knowledge of key

TABLE 2: Utterances of Numeracy Inquiry Community of Leader Educators' practice-related affordances.

Indicator	Practice	Practice		Practice	
		$N_q = 42$	f	$N_i = 8$	f
Physical resources	Cards and dice	33	52	6	8
	Homework books	17	25	2	2
	Flash cards	12	13	2	3
	Wooden cubes	9	9	5	6
	Alphabet-Mathematics cards	7	8	2	4
	Number Sense workbooks	5	5	2	3
	Edupeg workbooks	4	5	2	3
Conceptual resources, models and tools	Place value cards	34	53	3	3
	Fraction chart	13	16	4	4
	100-chart	13	13	0	0
	Number lines	5	5	1	1
	Bar model	5	5	2	3
Resources for learning about teaching	Watching demonstration lessons or videos	12	16	4	8
Teaching and learning theories	Socio-constructivism	32	63	7	11
	Learning environments need absence of fear and enjoyment of or satisfaction in learning	24	57	6	8

representations, models and tools for teaching mathematics. Almost all teachers noted in their questionnaires (38/42) that exposure to, and being given, mathematical conceptual tools such as place value cards (34/42), fraction charts (15/43), the 100-chart (13/42), number lines (5/42) and the bar model (5/42) helped in teaching particular mathematical concepts embedded within these manipulatives. Below we focus on those conceptual resources most noted by teachers in questionnaires and interviews.

Thirty-four of the teachers in the questionnaires and three in interviews explained that using the place value cards (also known as arrow or Flard cards) in their teaching was useful in developing learner understanding of place value. Such sets of cards are promoted for use and provided in the South African Department of Basic Education's 'Grade 3 teaching resource booklet' (www.thutong.doe.gov.za/ResourceDownload.aspx?id=39103). A number of international research studies have shown such cards to be useful in developing place value understanding and for fluency in naming three-digit numbers (e.g. Wright et al. 2006). The teachers were exposed to these cards during the first NICLE session, in which an invited presenter explained how to use the cards and multiple sets of cards were provided to every teacher for learner use. Additionally, in a subsequent session, one of the teachers, Melania, demonstrated using place value cards with a group of 10 learners. She brought her learners to the session for the demonstration. Many teachers commented on this session and the usefulness of these cards for supporting decomposing and composing numbers, reading three-digit numbers and understanding expanded notation. For example, NL4-6 wrote in the 2011 questionnaire: 'Flard cards – they help in understanding numbers. The place value of numbers. Learners can really see the place value of each digit'. While Everton explained in her journal of February 2012: 'Dane wanted to know how to divide 150 by 2. Courtney suggested breaking up into $100 \div 2$ and $50 \div 2$ and adding. Place value cards used'.

Data from both interviews and questionnaires noted that the fraction chart supported conceptual teaching of fractions. A range of literature promotes the use of fraction charts or fraction strips for supporting student understanding of fractions and comparison of fractions (e.g. Van de Walle & Thompson 1984). The excerpts from Calvin's and Everton's data illuminate the learning enabled by using these charts:

For children who don't understand, for example fractions, that is a concept that some of them don't. I will actually stick these fraction boards on their desks and I will say 'right if you are comparing fractions' (Everton, I, Nov 2012)

I have learnt a lot from this session. The way that I am teaching fractions needs a new approach. The learners must do more mental mathematics relating to fractions. I should let them count in fractions. I must always make sure that they have a variety of ways of representing fractions, e.g. fraction circles, fraction charts, strips, etc. (Calvin, Journal, May 2012)

Resources for learning about teaching

Twelve teachers in the questionnaires and four during interviews noted that the teacher demonstration lessons particularly enabled their teaching practices. Questionnaire responses about lesson demonstrations included terms such as 'useful', 'helpful' and 'interesting'. The following excerpts are examples of this:

I become more aware of the learners' actual and potential learning trajectory through observing simulated teaching at NICLE. (AR 4-7, Q, 2012)

To discern how certain activities aid the learning of concepts in maths by observing demonstration lesson by peers, and unpacking the unfolding of the lesson. ... I developed a sense of where it's coming from and where it's going. (AA6, 2012)

In addition, two of the teachers noted in questionnaires the value of watching a video of an international lesson. Classroom videos and lesson demonstrations have been reported to be strategic artefacts that convey realities, proofs and complexities of classroom events and practices (e.g. Ball 1996; Putman & Borko 2000; Silver 2009). Under sociocultural theory, 'demonstrations' and 'mimesis', such as videos, are community resources which are key for reifying a community's practices (Wenger 1998; Wenger et al. 2002). Demonstrations are also noted as being effective for context-bound understanding and enable learning experientially. The teachers' comments, the CoP perspective and the above-cited literature indicate that lesson demonstrations and videos present authentic classroom experiences that can powerfully illuminate mathematical ideas enabling strengthened teaching. This coheres with evidence from international literature that points to authentic teaching videos as useful resources for teacher development (see, e.g., Karsenty & Sherin 2017).

Mathematics teaching and learning theories

All eight teachers interviewed, and 40 of the 42 teachers in total, explained that engaging with specialists in NICLE improved their teaching, especially in terms of increasing learner participation. This coheres with the socio-constructivist perspective of learning promoted in the curriculum and NICLE. Increasing engagement with learners' sense-making, and increasing learner activity (including written activity), was a key goal in NICLE. The excerpts from two questionnaires, and from Melania's interviews and journal data, illuminate the learning noted in utterances related to adopting learner-centred practices:

I allow learners to explore more and giving them more time to think and allow them to explain their procedure or thinking and how they got to an answer. (GL5-7, Q, 2012)

I have been encouraged to build on learners' contributions, thus giving them confidence. (SE4-6, Q, 2012)

It [NICLE] just sharpened my awareness ... about interacting more with children and having them explain to you how they are thinking how they are working out problems from that perspective, definitely it has saved my teaching because I have communicated more with the children about how they are doing things and why they are doing things. (Melania, I, Oct 2011)

Learners must be able to explain why and how they did things. Think, pair and share – work together. ... (Melania, Journal, May 2012)

In addition, teachers noted creating a more relaxed 'learning can be fun' ethos and an openness to a variety of learner methods and contributions. Emphasising that mistakes and a variety of different learner contributions are rich opportunities for learning was a consistent message in NICLE. This was emphasised in NICLE generally, as well as specifically in a session in which a local psychologist spoke about the way in which fear can block learning. Mary and Robert explained:

I have become more holistic in my thinking, there isn't just one method in maths and it is important to allow children to explore and work things out for themselves. I try and make maths fun for my learners and use a variety of approaches because not all children learn in the same way. (Mary, Q, 2012)

I think personal enjoyment is always activated, I would say, by playfulness. ... This year we had an activity where we had games. The playful nature of mathematics. It was refreshing, also energising on a personal note. You see to learn maths like not in a routine way. ... (Robert, I, Nov 2012)

Within the CoP perspective, teaching and learning tools or artefacts were part of NICLE's shared resources, which deepened teachers' knowledge and strengthened their teaching practices. Teacher responses showed that physical and conceptual resources such as the place value cards, fraction charts, empty number lines, the 100 number grids and the bar model (used for problem solving) were used by the teachers to support learner understanding of key mathematical concepts. Teachers noted that exposure to and engaging with NICLE's conceptual resources, models and tools, paired with an emotionally safe and 'learning can be fun' classroom ethos enhanced their teaching. This coheres with Darling-Hammond and Richardson's (2009) review of research into 'What matters' in teacher education where they emphasised the creation of communities of practice with safe spaces and trusting relationships that supported teacher activity and collaborative engagement on various activities.

Community-related affordances and participation enablers

All 42 teachers commented on at least one of the three community affordance elements (i.e. nature of relationships, forms of participation and interaction with experts) (see Table 3).

TABLE 3: Utterances of Numeracy Inquiry Community of Leader Educators' community-related affordances.

		Community			
Indicator		$N_q = 42$	f	$N_i = 8$	f
Nature of relationships	Friendly relationships	12	13	4	4
	Mutually respectful	3	3	5	7
Forms of participation	Sharing classroom experiences and practices	32	63	7	12
	Active participation	7	7	4	7
Interaction with experts	Guest speakers	13	18	4	6

Here we share the way teachers expressed these as enablers of their learning.

Nature of relationships

The nature of relationships as learning enablers received 27 utterances across questionnaires (16) and interviews (11) (see Table 3). Thirteen of the comments in the questionnaires related to friendly relationships, while three comments related to mutually respectful relationships. In the interviews, seven utterances related to mutually respectful relationships, while four related to friendly relationships.

The following excerpt from Ruth's 2012 questionnaire captures teachers' appreciation of the 'atmosphere' of NICLE:

Yes, I have learnt and I am learning. I love the attitude and the atmosphere – unlike departmental workshops that are patronizing and 'schoolish'! Participation is genuine, questions are challenging – being treated as an equal adult. (Ruth, Q, 2012)

Similarly, excerpts from Melania's interview and Mary's journal illuminate how they noted NICLE relationships as enabling learning.

Often you go to these Departmental things and they almost talk down to you. Like you are a teacher and you don't know what you're doing, you know. NICLE has really gone, from the onset, they are trying to help, they are trying to uplift, they are trying to improve, they respect you, you know. (Melania, I, Nov 2012)

What a dynamic spirit! Focused on problem solving using fractions. I would have broken out into a cold sweat if asked to explain that concept but she just has a way of helping us who are 'mathematically challenged' to understand. (Mary, Journal, May 2012)

Wenger et al. (2002:28) argue that 'a strong community fosters interactions and relationships based on mutual respect and trust'. Of particular interest is how both Melania and Ruth explicitly compared NICLE's regard for the teacher as a professional, as opposed to their subordinated experience in departmental workshops – this was emphasised as particularly important in the post-apartheid South African context in earlier research (e.g. Graven 2012). This coheres with international literature that emphasises the importance of establishing mutually respectful partnerships with teachers that foreground co-learning (teacher-as-learner and educator-as-learner, Jaworski 2006:204) and recognition of teachers as professionals and fostering friendly and egalitarian relationships in teacher learning communities (e.g. Grossman, Wineburg & Woolworth 2001). In this respect, Calvin commented on the nature of the bond and togetherness within NICLE as the 'camaraderie amongst us' and Robert emphasised that 'we are all co-learners'.

Wenger et al. (2002:37) explain that a CoP creates an atmosphere of 'openness and trust' and a place where it is 'safe to speak the truth and ask hard questions'. The relationships that existed between NICLE teachers, SANC staff and invited partners of the chair were noted to foster a sense of belonging to a community in which there was a safe

space for learning even where mathematical confidence was low. This enabled free engagement and interaction with facilitators, affording learning opportunities for all.

Forms of participation

Most teachers noted certain forms of participation in NICLE as enablers of their own learning. The majority of these utterances referred to the way in which participation involved sharing classroom experiences (63 in questionnaires and 12 in interviews), while 14 related this to the active teacher participation in sessions (seven in questionnaires and seven in interviews).

Sharing classroom experiences and practices: The form of participation noted by many of the teachers (32/42) in questionnaires, and by seven of the eight interviewed teachers, as an enabler of learning was that of sharing classroom practices and ideas on teaching resources. The sharing of teaching experiences was a focus of the start of each session in which through group discussions teachers reflected on their teaching experiences related to previous sessions. The two teacher-presented teaching demonstrations with learners during NICLE provided another opportunity for teachers to share their teaching practice. The following excerpts reveal some ways in which sharing classroom experiences enabled learning:

Exposure to other teachers. Discovering other ways of solving problems. Interacting with a range of maths teachers. I liked the interaction with the Foundation phase teachers because they are your experienced teachers in this regard. (GL5–7, Q, 2012)

The big thing is seeing other people do it and discussing it with them and finding out what your common problems are and finding solutions to those common problems. (Everton, I, Nov 2012)

Other teachers such as Pamela and Edna expressed the view that NICLE provided a context for sharing ideas on numeracy teaching ‘resources’. Ruth remarked how it exposed her to ‘relevant material’ to use in her mathematics classes. Other teachers said NICLE enabled opportunities for ‘meeting’ (Edna, BN3, GN4), ‘interacting’ (AS1, GL5–7, SE4–6), ‘team working’ (BC4–7) and ‘learning from other teachers’ (GB2, SR3, SE3). Such professional community engagements according to BC4–7 and SE4–6 allowed educators to ‘reflect’ on their work and ‘reinforce’ positive aspects in their practices.

Teacher data thus reveal how sharing classroom experiences and practices provided opportunities which enabled teacher numeracy practices to evolve, and developed a sense of belonging to the community. These findings concur with research that emphasises that sharing classroom experiences is an important source of teacher learning (e.g. Putman & Borko 2000).

Active teacher participation: The NICLE’s promotion and inclusion of active teacher participation in sessions were noted by seven teachers in the questionnaires and by four of

the eight interviewed teachers. The following excerpts are examples of this:

Yes, the different activities stimulated thinking and reasoning. In their small groups teachers discussed and questioned each other herein developing their mathematical inclination. (AR4–7, Q, 2012)

People come with different ideas with sessions and it demonstrates it is not just a talk show it is active participation, that keeps it lively. ... The interaction is not where you have to just be absorbing theoretical knowledge of someone else. (Robert, I, Nov 2011)

Similarly, Edna and Mary, respectively, in their second interviews noted that NICLE sessions were characterised by ‘actively involving and engaging’ forms of participation which involved ‘a lot of practical, concrete ... hands-on experiences’, which made it easier to implement such practices in their classrooms. The CoP theory as well as professional teacher development literature resonates with the sampled teachers’ comments that their active participation and practical experiences in the NICLE community created opportunities for the positive evolution of their primary mathematics practices. This coheres with the findings of Darling-Hammond and Richardson’s (2009) findings that active teacher participation and discussion of practical teacher experiences in professional development communities of practice are important for teacher learning.

Engaging with experts

Another aspect noted as an enabler of learning was access to, and interaction with, presenters and guest speakers. Half of the NICLE sessions during the period of the research study were presented by invited numeracy education specialists.

Interaction with session presenters and guest speakers received 24 utterances across questionnaires and interviews. Learning from specialists was noted by 13 of the 42 teachers in the questionnaires and by four of the eight teachers in interviews. Teachers explained that access to the invited ‘specialists’ and ‘experts in mathematics’ provided them with current information on numeracy teaching that enabled their learning. For example, AA6 wrote that NICLE ‘exposed [him] to the accumulated expertise, experience, skill and knowledge of a variety of mathematics education researchers and practitioners’ (AA6, Questionnaire, 2012). Similarly, BC4–7 and IL3 acknowledged the expertise of the invited NICLE presenters in ‘their field of work’ and ‘what they talked about’ which allowed them to ‘understand more’.

Aside from being knowledgeable, several teachers (Edna, Calvin, AN3, AM4, GR3, NL4–6 and SB4) noted that invited experts (which included teachers) addressed many of their classroom challenges. AN3 and SB4 wrote that the guest speakers helped them to ‘solve some mathematical problems’ (AN3) and ‘clarified uncertainties’ (SB4). Calvin, Edna and GR3 said that the invited specialists’ presentations tackled different and new ‘mathematical topics’, while some

remarked that presenters provided the teachers with 'up to date information' (SB4).

The following excerpts capture teacher views of the effects of engagement with guest presenters:

You are introduced to new concepts all the time. It's exciting and stimulating, and a lot of things you can relate to as well. You know? Like especially with the guest speakers. (Mary, I, Sep 2012)

Started NICLE today!!! Good to be back and to see the gang – oh the maths experts!!! Really enjoyed the TED clips. Made a lot of sense 'children do have different abilities and talents' and I think we are always so quick to label children who are different. (Mary, Journal, Feb 2012)

In CoPs, 'masters', 'experts' and 'old-timers' are critical for ensuring participants' learning and for identifying and confirming existing knowledge and new developments within a community (Lave & Wenger 1991; Wenger et al. 2002). In mathematics teacher education CoPs, the key role of experts and masters is foregrounded in the emphasis on the value of partnerships with teacher educators or researchers and in communities that foreground co-learning and partnerships among all participant teachers as experts in terms of their particular experiences of teaching (Jaworski 2006).

The data discussed above show that specific relations, forms of participation and invited experts provided opportunities for interactions, engagement and sharing classroom practices in the CoP. These supported teachers in their learning and appropriation of NICLE domain concepts and practices into their teaching.

Conclusion

An investigation of the NICLE teacher learning affordances and participation enablers across different data sources highlighted the importance of Wenger et al.'s (2002) fundamental structural elements of a CoP, namely domain, practice and community.

Cross-case analysis of empirical data related to these key variables revealed that the NICLE domain and practice resources were highly valued as key learning enablers. Furthermore, this learning was enabled because of the nature and ethos of engagement in the CoP. That is, the respectful participatory relationships in NICLE, which foregrounded teacher experience as critical in judging the value of resources, were seen to enable the adaptation and adoption of resources for teaching. The article has illuminated how domain, practice and community are interrelated aspects central to enabling mathematics teacher learning. This structural transformation of professional development towards a content-, practice- and community-focus transcends the limitations of more traditional forms of teacher 'workshops' or in-service training sessions and could usefully inform the design of teacher development programmes.

A key limitation of this research is that it has focused on teachers' written responses and verbal utterances of their experiences of participating in NICLE and their perceptions of how this has influenced their learning and teaching. Further research into how this perceived learning may be observed in mathematics teaching practice would strengthen and broaden understanding of teacher learning through participation in such CoPs.

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Authors' contributions

M.G. gathered the annual questionnaire data on teacher participation while P.P. was a doctoral student under her supervision and gathered interview and journal data on a smaller sample of teachers within the PD program. M.G. conceptualised the article and both authors contributed to the analysis of the data and the writing of the article.

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