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Editorial

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THE PROFESSIONAL DEVELOPMENT OF MATHEMATICS AND SCIENCE TEACHERS: INSIGHTS GAINED FROM AN ACTION RESEARCH PROJECT

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Abstract

This article demonstrates how the professional development of teachers in key subjects such as Mathematics and Science can be facilitated by means of action research in consideration of relevant learning theories. Since South Africa is faced with a shortage of qualified teachers in Mathematics and Science, the aim of this particular study was to promote the teachers' professional development at a selected primary school. The theories of socio-constructivist and situated learning were used as conceptual framework. The sample involved 14 teachers of one school who participated in the three-year study. The project implemented a three-stage model which involved a subject Community of Practice (CoP), and thereafter a grade CoP, before it was individualised for implementation by each teacher. Three different grade groups completed between two and six action research cycles involving about 30 meetings each. Programme evaluation was by means of observation, typed minutes, focus groups, individual interviews, teachers' files and learners' books and achievements. The results illustrate the professional development of these teachers by means of this model of action research which could be useful to secondary schools and higher education institutions, as well as to practitioners in other fields.

Keywords: action research, community of practice, mathematics, professional development, science, situated learning.

1. INTRODUCTION

Teacher professional development is crucial to foster educational change (Butler & Schnellert, 2012:1206). We argue that the professional development of practitioners in any profession could be facilitated by means of action research which is informed by relevant theories such as socio-constructivist learning and situated learning. This article illustrates this reasoning in the context of the professional development of a group of teachers at one school. In this study, 'professional development' refers to the improvement of the teachers' knowledge, skills, beliefs and attitudes in the fields of Mathematics and Science (Fishman, Marx, Best & Tal, 2003:643).

In the subjects of Mathematics and Science, the teaching profession in South Africa is faced with a shortage of qualified teachers (Gilili, 2018:1; Henning, 2013a:139, 2013c:143; Kriek & Grayson, 2009:1; Oliver, McConney & Maor, 2009:6; Oosthuizen, 2016:1), which causes great concern considering the

significance of these subjects for economic growth (Schulze & Lemmer, 2016:1). Many practising teachers have limited knowledge of the subject content and of child development psychology, practice ineffective pedagogies, and display unprofessional attitudes (Henning, 2013a:139, 2013b:56; Kriek & Grayson, 2009:1; Motshekga, 2010:1; Schulze & Van Heerden, 2015:7; Venter, 2010:1). Consequently there is a lack of quality learning outcomes in these subjects. This was revealed by international test results such as the Trends in Mathematics and Science Study (TIMSS) in which South Africa's learners scored extremely low in comparison to other countries (Human Science Research Council, 2012:4). Poor learning outcomes were also illustrated by the Annual National Assessment (ANA) results published in 2014 when the learners underachieved in Mathematics and English as a first additional language on national level. For example, the Grade 4 average for English was 41% and for Mathematics 37% (Department of Basic Education, 2014:8).

To address the above-mentioned problems, the Department of Basic Education implemented in-service teacher development programmes. However, a 2013 publication reported these courses to be “poorly contextualised, of short duration and without demonstration, modelling or follow-up at school level” (De Clercq & Phiri, 2013:80). Such top-down initiatives have also been criticised by others such as Butler and Schnellert (2012:1206). In addition to a lack of sensitivity to local contexts, they fail to capitilise on local knowledge in the school community, and weaken or undervalue the decisive role of teachers. Ideally, teacher development should be school-based to enable and motivate teachers to take responsibility for effective learning (De Clercq & Phiri, 2013:80; Mestry, Hendricks & Bischoff, 2009:488). To this end, several researchers argue for a reculturing of education through collaborative interaction of teachers within professional learning communities (Anderson, 2007:10; Bubb & Earley, 2007:1; De Clercq & Phiri, 2013:80; DuFour, 2004:9-10; Eraut, 2004:267; Ferguson, 2006:4; Gajda & Koliba, 2008:133; Johnson, 2009:5; Pappano, 2007:1-4).

Reculturing implies going against a practice where teachers work in isolation to teachers working collaboratively, observing each other's lessons, sharing teaching strategies, and routinely focusing on pedagogy, including assessment (Anderson, 2007:10; Bubb & Earley, 2007:19; Ferguson, 2006:4; Horne & Hotchkiss, 2007:1; Johnson, 2009:3; Wong, 2004:52). Reculturing requires of teachers to lay bare their assumptions, strengths and weaknesses before their colleagues. Professional development along these lines suggests that “meaningful, sustained changes in classrooms are fostered by engaging teachers jointly in locally situated, inquiry-based, longitudinal, and critical examinations of practice” (Butler & Schnellert, 2012:1206). Such an approach to teacher development requires the active support of school leaders to be successful (Servage, 2008:71; Pappano, 2007:1). One way to facilitate this kind of professional development is through an action research approach as also recommended by others (Gajda & Koliba, 2008:136). Thus the research

question that guided this project was: How can Mathematics and Science teachers at one school be developed professionally through action research? The school where the project was implemented was an English-medium primary school with 35 teachers and about 800 learners. Most learners were black, which meant that English was their second language, presenting huge challenges regarding learners' understanding of concepts in Grade 4 and beyond when English is the only medium of instruction (Henning, 2013b:56). At the school, the learners did poorly in Mathematics and Science in comparison to their other subjects; it was also noted that some teachers lacked general subject content knowledge, for example, they confused the 'smaller as' and 'greater as' signs in algebra. Added to this was Henning's (2013a:139; 2013b:56) findings that teachers lacked insight into child cognition in general, and subject pedagogy in particular. This resulted in many teachers relying on 'talk and chalk' or simply using textbook exercises and worksheets developed by others without reflecting on their own ability to develop context appropriate learning material. They also tended to work in isolation from one another. The above served as impetus for the study which was planned in consideration of two theories in particular, namely socio-constructivist and situated learning theories.

2. SOCIO-CONSTRUCTIVIST AND SITUATED LEARNING THEORIES

A socio-constructivist viewpoint merges social and cognitive perspectives on learning. From a social perspective, practitioners (e.g., teachers) learn best when working in a community in which they cooperate through relevant action and discourse (Schlager & Fusco, 2003:210). The experiences, skills and strength of individuals are harnessed to assist in the development of all, while the community supports and encourages members to grapple with new ideas (Chalmers & Keown, 2006:148). From a constructivist perspective, learning is a sense-making process where practitioners (e.g., teachers) build new knowledge and understanding on the foundation of their existing knowledge and perceptions in authentic learning environments (Chalmers & Keown, 2006:583-584; Slepkov, 2008:96). This brings to light the role of scaffolding of new learning and suggests that learning would be more likely to lead to change when it fits into the already existing schema of the teacher as learner. For meaningful learning to take place, teachers also need to reflect on their constructed knowledge and beliefs (Chalmers & Keown, 2006:148).

Situated theorists also emphasised that cognition is related to context and intention (Lave & Wenger, 1991:49), and that learning occurs through participation in activities that are distributed between the individuals, tools and artefacts of a community of practice (CoP) (Mason, 2007:2), also called a professional learning community (De Clercq & Phiri, 2013:80). Lave and Wenger (1991) conceptualise learning as coming to know how to participate in the discourses and practices of a particular community. Learning is as much a matter of enculturation into a community's language, values and ways of

thinking as it is a result of explicit instruction in specific concepts, skills and procedures. Lave and Wenger (1991) and Wenger (1998:2) call the participation of novices 'legitimate peripheral participation'. In the context of this paper, novices were those teachers who have not yet acquired the necessary expertise to teach Mathematics and Science effectively. As trainees master the knowledge and skills of their trade, they move towards more central and full participation in the community. Not only the individual, but also the community changes in that new ways of thinking are established (Hodkinson, Biesta & James, 2008:32). Since learning is distributed among people it is possible for teams to accomplish tasks beyond the capabilities of individual members. Henning (2013c:141-155) has demonstrated the value of a research CoP with a study that also focused on the learning of Mathematics of South African Foundation Phase learners.

In consideration of the above exposition, an action research plan was designed for the professional development of the Mathematics and Science teachers.

3. THE ACTION PLAN FOR PROFESSIONAL DEVELOPMENT

The duration of the project was three years and the aim was to develop the teachers' knowledge of and skills in teaching Mathematics and Science effectively. To this end the specific objectives were to facilitate the teachers' ability to reflect on and develop context appropriate teaching methods and assessment techniques in subject and grade communities of practice; to improve the teachers' professional attitudes and to provide evidence of good learner achievement (a 90% pass rate and a 60% average on high-quality assessments). In the first planning phase we determined the teachers' needs and took decisions about meeting dates and times and work roles. The sessions were recorded and transcribed.

The school roster that was followed during the year was divided into six school days, called a 'cycle'. The teachers met once a cycle (about 30 meetings per year) for a maximum of two hours to plan content as well as teaching methods (taking into consideration learning theories and child cognition), suggest resources, plan assessment strategies, undertake analyses of results and decide on intervention strategies. Each teacher was responsible for the initial, tentative planning of one or two subjects before meetings took place during which extensive discussions took place.

The model that was implemented constituted a multifaceted “community of inquiry in action” (Butler & Schnellert, 2012:1216). The teachers participated in three levels of activities: (i) The first level was participation in a subject CoP. The Mathematics CoP, for example, comprised Mathematics lead teachers from each grade who would meet with their own Head of Department (HOD) at least once a term. In this CoP the lesson and assessment planning for a cycle was initiated and quality-assured, and then brainstormed with peer teachers.

(ii) The second level of planning was in a grade CoP. A Grade 4 CoP, for example, comprised Grade 4 teachers who taught a variety of subjects. (iii) The third level of planning occurred when teachers planned individually for classroom interaction based on the needs of their own learners. By this time, the teachers had clear instructional plans, as recommended by Muthukrishna (2013:125). These plans were not prescribed recipes since the teachers were expected to reflect on best practice in their own contexts. The school provided the project with resources, one of which was a university academic who acted as non-school-based expert, as advocated by Maistry (2008:119).

During a typical meeting, lead teachers would take turns to present the work plan of a subject for the next six-day cycle. This was often done in consultation with subject HODs. The expectation was that lead teachers would be thoroughly prepared, follow the topics prescribed in the syllabus, and include examples of assessment activities after sequences of lessons. Assessment marks were reflected on and teachers brainstormed ideas for remedying poor performance. This action plan was implemented and evaluated in participatory action research cycles.

4. RESEARCH METHODS

Action research is systematic inquiry and critical reflection by practitioners such as teachers, to improve their daily practice (McMillan & Schumacher, 2014:1). Participatory action research in this study allowed collaboration of the school management team, teachers and an outside expert (Strydom, 2011:491, 492). The purpose of the action research cycles was to exploit the benefits of grade and subject collaboration for the professional development of teachers.

The sample was a purposive selection of 14 class teachers: five Grade 4 teachers; five Grade 5 teachers and four Grade 6 teachers. Since they were from various races, many of them were also English second language speakers. One of the class teachers in each grade was the grade leader. Table 1 provides some background information about the teachers.

Table 1: Background information of teachers

Group	Number of teachers	Age range (yrs)	Years of experience	Cycles completed
1. Grade 4	5 (A - E)	22 - 51	4 - 31	6
2. Grade 5	5 (F - J)	26 - 54	3 - 32	4
3. Grade 6	4 (K - N)	27 - 37	4 - 15	2

Table 1 illustrates that the groups were diverse with regard to age and years of experience. The study started with Grade 4 in the first year, followed by Grade 5 a year later and Grade 6 another year after that, enabling us to follow the same group for three years. However, two individual teachers who left the school during the three year project were replaced by two others.

Ethical clearance was obtained from the university (2013 May/35590084 /CSLR). We also included three unifying ethical principles namely: (i) Respect for persons (which included autonomy, informed consent and the confidentiality of participants), (ii) beneficence and (iii) justice (Nolen & Van der Putten, 2007:400-402). Teachers were assured that participation in the data collection phase was voluntary.

Data were collected continuously during the three years that the project was implemented. The data were collected through participant observation and field notes, end-of-term reflection meetings attended by all participating teachers, individual interviews, focus groups and document analysis. Participant observation enabled us to build a picture of the worlds of the teachers and an understanding of how they went about their activities (Strydom, 2011:491). It allowed us to observe how teachers planned and communicated with their peers. These observations were recorded as field notes, although meetings were also digitally recorded for transcription. Very often "member checking" was used to verify the information. End-of-term reflection meetings were held twice a year and were audio recorded and transcribed verbatim. Twelve of the 14 participating teachers were also interviewed individually at the end of the project. Each participant was asked: *What have you learnt by participating in this programme?* Probing enabled the participants to reflect on the project (Strydom, 2011:492). The interviews were recorded and transcribed verbatim. Three focus groups (one with each of Grade 4, 5 and 6 teachers) were also conducted at the conclusion of each year to determine what did or did not work well, and what could be improved. These focus group meetings were also recorded and transcribed verbatim. The documents that were analysed included minutes of CoP meetings, book control reports, mark analysis documents (to note learner achievement), and graphs, lesson plans, assessment plans, moderation reports, and field notes. The large volume of raw data from different sources increased the trustworthiness of the findings.

The data were analysed by identifying and coding segments of meaningful data, for example "creative assessment activity" or "appropriating knowledge". These codes were refined and then later grouped into categories. Both authors checked the codes for inter-code reliability. For the purposes of this article, the main findings are presented and interpreted, supported with the most illustrative quotes.

5. RESULTS AND DISCUSSION

5.1 First-level participation in a subject CoP

Participation in the subject CoP of Mathematics and Science enabled the teachers to obtain membership of these communities in line with another study (Mason, 2007:2). Observations noted in a field journal and interviews showed that the teachers' participation was characterised by taking part in as well as by being part of the subject CoP. The knowledge shared in the subject CoP gave each lead teacher access to the craft knowledge of the experienced subject HODs who served as mentors, in accordance with the views of, for example, Street (2004:9). This developed the teachers professionally as they reflected on and debated cognitive insights and teaching methods and constructed new understandings. This is in line with situated learning theory that views "innovation, apprenticeship, social learning, shared interest, and collaboration" as core characteristics of a CoP (Henning, 2013c:148-149). As the teachers explained:

> *In this context, there is guidance, there is feedback ... and you are constantly engaged in discussion. I have grown. I am able to speak more and express myself more. As a new teacher, this definitely works.* [Teacher F, lead Mathematics teacher, interview.]

> *If you've got something designed in a certain way and you are submitting it to your HOD, your HOD has the authority to change it according to what he or she thinks by saying: "I suggest you do it this way" – suggest – and that's where you need to have the collaboration, saying: "This is why I've done it this way [and this is] what my reasoning behind this is". Then you and the HOD can negotiate based on reasoning.* [Teacher K, lead Mathematics teacher, Grade 6, focus group.]

5.2 Second-level participation in a grade CoP

In this scenario, the teachers were positioned as both receptors and creators of knowledge. Similar to the participants in a previous study (Geyer, 2008:627), it was observed that the teachers actively reflected on how to implement their ideas appropriately at their grade levels. In their CoP, they were expected to link the subject content with the grade through discussions that considered the fact that the learners functioned on a concrete level of cognitive development. This required a shift in pedagogy since Henning (2013a:139) reported a lack of teacher consideration of child cognition in teaching practice. Situated learning theory also emphasises that cognition must be linked to context (Lave & Wenger, 1991) to enable the teachers to develop new insights.

However, teacher learning was not instant but more gradual. Observation revealed that for the first two years of the study, most lead teachers adopted a transmission mode strategy: 'Lesson one: do this; Lesson two: do that'. This positioned the lead teachers as “experts” who instructed, while the peer teachers were passive, inferior and needed to obtain the required information (Chalmers & Keown, 2006:148). With time, the grade CoP facilitated a team-mindedness among members, and a reform orientation to the mediation of the lesson and assessment planning that illustrated their professional development. The Mathematics lead teachers led the way by providing worksheets with detailed, written explanations of how these should be used, often accompanied by a teaching aid. Providing resources (such as learning material, assessment tools, colleagues and mentors) to the teachers who immersed in action research learning cycles are crucial to establish research-practice associations (Butler & Schnellert, 2012:1217). Two teachers explicated the learning that took place within a Mathematics or a Science CoP:

> *The first time that we got here we just handed out notes. We said: “You have to do this on day one, you have to do this on day two.” But now you must come with your planning and explain to the teachers exactly where you are going with this. You must have some idea of what and how the children learn and you have to share that with the teachers.* [Teacher A, lead Mathematics teacher, Grade 4 focus group.]

> *There has to be a lot of explanation, because one disadvantage of worksheets, they encourage laziness. Then I don't have to research, I only need to understand the four points on the worksheet. It's the worksheet plus explanations in our level meetings that helps us to learn. The more we talk about it, the more I am also gaining as a teacher. I am ready for any questions a learner might ask me.* [Teacher E, peer teacher, interview.]

5.3 Third-level individual preparation

In the third level of planning, the control shifted to the individual teachers who needed to plan very deliberately for their own classrooms. This stimulated reflection to make sense of their previous discourses, the resources provided in the subject and grade meetings, and how they could scaffold learning in their classes (Chalmers & Keown, 2006:583-584; Geyer, 2008:627). In interviews, the teachers indicated that they would often prepare their own charts, flash cards and worksheets. They would go over the mathematical problems more thoroughly on their own and practice conducting experiments at home, thus developing personal knowledge. The following comments are illustrative of the above mentioned professional development that occurred:

The planning is very, very detailed. You cannot just look at the planning and teach. You've got to go home and you've got to research. Like the exercises which are written down…you've got to go and work it out, which is good. [Teacher F, lead Mathematics teacher, interview.]

> *You have to look at the worksheets because you go back to your lead teacher and you say: "This doesn't make sense." And you're either right, because you picked up a mistake, or you're wrong, because you did not understand it.* [Teacher B, lead Natural Science teacher, interview.]

The extent to which teachers undertook this level of planning was easily observed by means of a book control. Some teachers merely pasted in or filed the notes and worksheets that were provided to them. Others wrote methodological tips for themselves or wrote reflective notes on the effectiveness of the approach used, thus illustrating how they developed professionally. HODs increasingly insisted on seeing evidence of this planning. For example:

> *The planning we've accepted up until now has literally been like teacher A's planning copied in teacher B's file. That's not your planning. So what I say is ... now that you feel comfortable and you've got all your stuff from last year and this year … now you [must] take what she gives you and you [must] write your own planning. It must be in your handwriting with your own reflection. And feel free to indicate what didn't work. We need to see that you took the notes and gave some thought as to how to implement it. This is also so that we can discuss if it was a good lesson or needs improvement.* [Natural Science HOD, Grade 4 CoP.]

5.4 Problems experienced with planning and participation in the CoP

Interviews and observation notes revealed that a number of problems inhibited the effective functioning of a CoP, as also found in other similar studies (Gajda & Koliba, 2008:133; Hew & Hara, 2007:592; Johnson, 2006:237). In one example, Butler and Schnellert (2012:1216-1217) were concerned about the variability in the extent of engagement in the inquiry process of participating teachers. In the study on which this article reports, challenges included the poor work ethics of a lead teacher and of a HOD. Peer teachers in the grade CoP would receive very poor quality work or no work at all. This was a recurring problem in Grade 5 Natural Science in the first two years of the study. The following comment is illustrative:

> *People don't have a sense of time management. The lead teacher gives work for three periods when there are six [periods] or does not hand in assessments on time. They don't realise the effect that it has on the entire team and the child.* [Mathematics HOD, Grade 5 focus group.]

Many lead teachers struggled to adopt non-traditional pedagogies; some peer teachers were uninvolved in the knowledge-sharing discourse because of

deeply ingrained individualism; passive peers did not hold lead teachers accountable for poor planning or did not want their own lack of knowledge exposed. These challenges also occurred in other contexts (Gajda & Koliba, 2008:133; Hew & Hara, 2007:592;.Jita & Ndlalane, 2009:58, 66; Johnson, 2006:237). For example:

> *When the Natural Science planning comes I'm not happy but I don't know how to tell teacher G: "You know what, I don't like this, I'm sorry I don't know where this is going to".* [Teacher F, lead Mathematics teacher, interview.]

> *I realised that sometimes, in the grade CoP, the teachers say they understand but they don't really...they are sort of scared. When I look at this "bigger than" and "smaller than" sign, then I realise that they don't know how to read it.* [Teacher A, lead Mathematics teacher, Mathematics CoP.]

Finally, we observed that particular teachers failed to make any effort with personal preparation for classroom implementation, possibly related to a fear of confronting their own inadequacies. This led to the following: Teachers would do more Mathematics lessons in Natural Science lesson time, or take a small topic in Natural Science and draw it out over a whole week. Peer teachers who did not understand the work would adopt avoidance strategies by postponing certain lessons, making arrangements with the lead teacher to switch classes, or disrupting their colleagues' lessons to request support. Such techniques constrained the teachers' professional development and slowed their progress towards more full participation in the subject CoP.

5.5 Professional learning gains

During interviews and focus groups at the conclusion of the study, the participants referred to their own professional development. Shifts took place in their subject knowledge (improved insight); teaching methods (greater variation and creativity of representations and activities); and assessment plans (better quality). Other learning gains that were mentioned included better teacher reflection; improved professional attitudes (e.g., enhanced subject ownership, time management, meeting deadlines and being accountable for planning and achieving good results); greater teacher efficacy built by improved learner achievement and improved HOD mentoring and moderation skills. For example, lead teachers often shared information on how to teach a topic, highlighted the difficulties the learners might experience and suggested ways to overcome these. One teacher suggested:

> *When you are doing your revision, don't just put it up on the board and let them do it. Take each question and read it out to them, explain it to them and then make them do it. Then we mark it and move on to the next question.* [Teacher E, lead Mathematics teacher, Grade 5 CoP.]

The teachers gained in their understanding of subject content and methodological repertoires, although they seldom referred to child cognition, as Henning (2013a:) also found. Teachers began to buy into the idea of making the subject "alive" in class. In the Mathematics classrooms teachers used practical aids such as flash cards, geometric shapes and Unifix blocks; they did symmetry, tessellations and measurements practically, instead of teaching it purely from pictures and worksheets; and stories were told to make addition, subtraction and fraction problem-solving interesting. In Science, more experiments and projects were undertaken. In line with constructivism, these authentic activities fostered connections between the learner and his/her real-world experiences, which motivated learner engagement (Walshaw, 2012:425). For example:

> *I found with the vegetative reproduction, for [the learners] to actually see that strawberry plant was amazing. Today I brought a potato. They were wowed by it! They don't like to see me standing there just "blah, blah, blah". So, have a partner with you all the time – be it a chart or whatever.* [Teacher F, lead Natural Science teacher, Grade 5 CoP.]

> *In maths, practical work is important. If they do things more practically, they will learn more. You can't just tell learners there are 10 mm in a cm. You have to tell them go and count those little lines, or make a little ruler.* [Teacher A, lead Mathematics teacher, interview.]

Creative suggestions were made to improve the work ethic of learners and foster a homework mentality in the learners and their parents. Fullan (2007:35-36) regards this as "connecting" to the outside world. This connection was given as a reason for the improvement in the learners' achievements. For example:

> *If you give learners homework every day, you must get the parents involved. When I write a note in a diary and say: "Your child doesn't understand multiplication," I see the parents respond. It is amazing!* [Teacher A, lead Mathematics teacher, Mathematics CoP.]

Regarding improved teacher reflection, Geyer (2008:627) viewed this as important to enable teachers to teach for conceptual understanding. For example:

> *I looked at myself… my Mathematics average was too high. It was ridiculous. I thought the test was a good standard, but it was not. The kids are getting better. When the kids get better, we've got to up our game. So that's a learning curve for all of us.* [Teacher K, Grade 6 CoP.]

With regard to internal assessment practices, the HODs and lead teachers favoured class tests, practical tests and examinations as reliable forms of assessment, rather than rubric-based posters, presentations and demonstrations. In addition, learners wrote external tests such as the common quarterly examinations set by the district office and the ANAs. This was another way in which the school connected to the outside world. Such external assessments challenge and support teachers in their professional development. In our study, the teachers learnt how to phrase questions differently, using proper language. Thus, the learners became familiar with the terminology such as “equivalent”, “symbols”, “compare” and names of fractions. Under the guidance of the HODs, who moderated every test, the lead teachers became skilled at setting assessments and awarding marks according to a relevant taxonomy. The idea was that no assessment should allow the majority of the learners in a class to get full marks.

At first, the teachers would not discuss the tools of assessment (memoranda and rubrics). They would also mark only their own learners' work. This created many problems because of misconceptions and inconsistencies in the marking. What worked best was when the test was scheduled by all peer teachers and written by their learners, and then marked by or together with the lead teacher, or when teachers marked the learners' scripts of their fellow teachers. This aided the teachers' development since it encouraged discussion and led to a common understanding of what was required regarding teaching and assessment. One peer teacher said:

> *I like what we do in Mathematics – we all write the test and then we discuss the memos. It is much better … it makes more sense.* [Teacher H, peer Mathematics teacher, end-of-term reflection meeting, Grade 5 CoP.]

The discourse around test answers was vibrant and took teachers into uncomfortable moments of disagreement as they strived to reach common understandings. Such encounters are crucial for developing new insights and ultimately for their professional development (Butler & Schnellert, 2012:1206).

A significant benefit of a three-year study with continuous data analysis was that differences in teacher development were revealed. Some teachers were able to facilitate better learner achievement and this motivated those teachers even further, as Kriek and Grayson (2009:1) also found. Lead teachers started to exert more effort on their planning and tried out new ideas with the support of their HODs.

The attitudes of teachers toward external assessments also improved. They acknowledged that having a professional attitude meant moving on from being excuse-driven to being solution-driven. This was especially important in the context in which they worked, since the learners needed constant

engagement and encouragement. The teachers also adopted attitudes characterised by a team-work mind-set in line with Lave and Wenger's (1991) notion of situated learning and with socio-constructivism. This was observed when lead teachers fully embraced the responsibility for their subject planning and for building the capacity of peer teachers. Once peer teachers realised that the project would benefit the learners, they improved their participation in the CoP and became receptive to ideas from lead teachers and other peer members.

6. CONCLUSION

This article explains how action research cycles can be used for the professional development of practitioners – in this case, of teachers. It is a reflection on a three year project with a group of primary school Mathematics and Science teachers implementing a three-stage model, and completing several action research cycles.

Although the study was limited by a lack of active cooperation by some teachers, the study revealed significant professional gains for others. By being involved in different levels of communities of practice in continuous action research cycles, the teachers learnt through a collegial reflective culture in a context-sensitive way. The study revealed professional gains in the areas of subject content knowledge, assessment literacy and professional attitudes in particular, as shown in sections 5.1, 5.2 and 5.5 in particular.

To develop practitioners of any profession, several action research cycles of a high quality are advocated, with the active support of management and outside experts. A system of distributed leadership is recommended (exemplified in this study by lead teachers for every subject per grade and HODs for each subject). Moreover, the learning theories of socio-constructivism and situated learning in communities of practice are generic theories which may be useful in professions other than teaching. Professional development of practitioners of any kind benefits a country - this is particularly true of the development of South African teachers in Mathematics and Science.

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