



A LITERATURE STUDY ON COLLABORATIVE PROFESSIONAL DEVELOPMENT AS A VEHICLE FOR THE SUCCESSFUL PRACTICE OF INQUIRY-BASED LABORATORY WORK IN SCIENCE CLASSROOMS

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ABSTRACT– Currently inquiry is espoused in most science curricula. It is one of the central themes defining teaching and learning strategies for the envisaged educational reforms in school science by national education departments. By nature, laboratory work is well positioned as a vehicle that both teachers and learners can use to practice inquiry meaningfully. However, teachers often struggle to incorporate inquiry in school science laboratories. Considering that teacher professional development is one of the anchors of successful educational change, in this paper I present an overview of the pivotal role that some collaborative professional development approaches play in the effective incorporation and practice of inquiry-based laboratory work in school science in South African schools. The overview was developed after an extensive review of South African and international literature on teacher professional development in relation to the practice of inquiry-based school science laboratory work. The Vygotskian co-construction theory was selected as a framework to serve as a filter in the synthesis of literature in order to define the scope of collaborative professional development approaches. Accordingly, arguments are presented on how collaborative professional development can be used as a vehicle to successfully usher the desired change towards the widespread and successful practice and incorporation of inquiry in school science.

Keywords: Collaborative professional development (CPD); Laboratory work; Inquiry-based laboratory work.

1. INTRODUCTION AND BACKGROUND

While the concept of on-going professional development for teachers is widely endorsed, debates revolving around effective frameworks that help to score resounding successes have taken centre stage. Kriek and Grayson (2009) state that professional development is not new, however, there is a revamp in the manner in which it is being structured by way of reconceptualization. This might be as a result of what Dass and Yager (2009) refer to as a paucity of effective professional development models for science teachers that translate to improved student learning. This is significant in science and mathematics education where learners' poor performance has reached national crises proportions in some countries, as indicated by the Glenn Commission of 2000 (Loucks-Horsley, Stiles, Mundry, Love and Hewson, 2010) and the TIMSS reports (Spaull, 2013). Literature reveals that proposed frameworks to achieve effective teacher learning that results in learner achievement are being aligned with teaching and learning theories entrenched in subject curricula for classrooms (Gulamhussein, 2013). One significant learning theory in science is inquiry-based instruction. From it emerge other specific teaching and learning strategies such as inquiry-based laboratory work. Reports that teachers do not effectively implement inquiry-based instruction in science education (Barrow, 2006; Williams, 2007) have in part influenced the writing of this paper. The teachers who are unable to effectively implement inquiry in their practice are the same teachers who are expected to transform teaching and learning to incorporate inquiry. Harlen and Allende (2008) point out that the practice of inquiry-based science education requires that teachers use skills that are different from the traditional science teaching skills, hence the need for specially structured professional

development. Loucks-Horsley *et al.* (2010, p4) observe that, 'Science and Mathematics content and pedagogical content knowledge are playing a greater role in professional development programmes'. This observation also in part provides the foundation and motivation for this literature study on how collaborative professional development can serve as a vehicle for the successful practice of inquiry-based laboratory work in school science. Similarly, the guiding theoretical framework is drawn from collaborative teacher professional development models based on Vygotsky's theory of co-constructivism. Accordingly, this paper addresses the following research questions,

1. Why does the state of Inquiry-Based Laboratory Work (IBLW) practice in schools need transformation through effective teacher professional development programmes?
2. What collaborative professional development opportunities for the successful practice of IBLW are presented in literature?

There is an increasing scholarship on collaborative professional development (CPD) as a viable approach to teacher learning. However what is apparent is a paucity of teacher learning activities that are grounded on the defined principles of what constitute CPD. Dass and Yager (2009) point out that while there is a considerable base and much consensus on effective professional development on one hand, there is also a significant gap between knowledge and practice on the other hand. Literature is very affirming and in agreement that incorporating the underpinning principles of CPD in teacher learning translates to the attainment of most curricula visions. CPD approaches are depicted as a novel idea presented as an alternative form of teacher professional development to traditionally practiced approaches (Ono & Ferreira, 2010). Hargreaves and Dawe (1990) posit that CPD is not merely peer coaching that result in contrived collegiality to enhance administrative controls. It is rather an innovative culture of openness, trust and support among teachers for development rather than implementation (*ibid*). Accordingly, there are calls to remodel teacher professional development because the approaches used currently are widely reported to be ineffective (Gulamhussein, 2013) and lacking in opportunities for continuous and long term development (Loucks-Horsley *et al.*, 2010; Rodrigues, 2005). The ineffectiveness alluded to is in terms of promoting teacher learning that leads to improved student learning (Kafyulilo, 2013; Timperley, 2008). With increasing efforts to integrate teacher professional development in education reforms and policy shifts (Nakabugo *et al.*, 2011), it has become abundantly clear that teacher professional development has to form an integral part of teacher practice as an ongoing process (Dass & Yager, 2009). The departments of Basic Education and Higher Education and Training (2011) enshrine continuing professional development in their integrated strategic planning framework for teacher education and development in South Africa. Nakabugo *et al.* (2011) even suggests that teacher education should be in the form of a continuous process that begins with pre-service education and complemented by a strong, on-going, in-service professional development programme. This is opposed to the once in a while experiences of professional development that may be availed to teachers (Dass & Yager, 2009; Fraser-Abder, 2013; Rodrigues, 2005). These occasional teacher development exercises have been heavily criticised in the literature reviewed for doing little to transform teacher practices that would result in improved student performance as initially intended (Bilbao *et al.*, 2013; Dass & Yager, 2009; Ono & Ferreira, 2010). The activities have been associated with the traditional teaching and learning theories, which are not in line with current curricula orientations (Gulamhussein, 2013). Accordingly, there are calls from literature to develop frameworks for teacher professional development that deliver the desired outcomes for sustained teacher professional transformation in terms of continuous learning and ultimately improved student learning (Kriek & Grayson, 2009; Ono & Ferreira, 2010; Rout & Behera, 2014). Loucks-Horsley *et al.* (2010:4) assert that, 'Profession development has become more powerful and is being designed more often with an intention of improving student learning.'

2. THEORETICAL FRAMEWORK

In the wake of a wide scholarship currently available on collaborative professional development approaches for science teachers, the scope of the study had to be defined by providing a theoretical framework to help sift through many arguments and findings presented for relevance. Accordingly, four assumptions were selected to delimit the search for relevant collaborative professional development approaches. First, teacher professional development has been found to be more effective when it is structured as an on-going process (Dass & Yager, 2009). Second, professional development should be school-based and embedded in teacher tasks to ensure sustainability (Rout & Behera, 2014). Third, learning theories for professional development should be aligned with teaching and learning strategies embodied in national curricula (Gulamhussein, 2013). This is to avoid dissonance between teacher beliefs and curricula visions. Fourth, professional development approaches should be well-supported and widely recommended by research findings. These study assumptions were used in conjunction with a theoretical lens in the form of Vygotsky's theory of co-construction. This was necessary because in the current literature there are several forms of collaborative professional development approaches that have been developed as alternatives on the basis that traditional approaches render teachers as passive receivers of information. The main reason for using Vygotsky's co-construction theory is encapsulated in the following statement by him: 'What a child can do today in co-operation, tomorrow he will be able to do on his own' (Vygotsky, 1962, p87). This can be extended to teacher learning during professional development exercises. Reusser (2001) elaborates on the theory by saying that learning during peer interaction, learning in teams and computer aided collaborative work can be achieved as participants engage in the elaboration of mutual understanding and knowledge, and jointly construct shared understanding by giving and receiving help. Thurston *et al.* (2007) further elaborate that the cognitive development of peers engaged in learning through the Vygotskian co-construction approach can be at different levels but should not be too far apart. It is expected that as the teachers co-construct knowledge during peer learning and tutoring by reaching consensus through co-constructing knowledge, the gap between their levels of cognition becomes smaller. The notion that most learners have prior concepts about science is a rich medium for learners to engage in co-construction (*ibid*). This realisation has also been extrapolated to provide an assumption for teacher learning in this review. Most teachers have developed some concepts about science and inquiry-based science teaching and learning. This serves as an enabling medium for teachers to engage in peer learning through co-construction. The choice of the Vygotskian co-construction theory has been made on the basis of its specification that peers engaged in learning have cognitive development levels that are close to each other. This ensures that professional development may take place in schools even when there is no external intervention from specialists. Professional development would then be school-based and if it is well integrated with other school activities it becomes an on-going sustainable process. The choice of the theoretical framework serves to distinguish the form and strain of constructivism to guide the forms of collaborative professional development approaches discussed in this research study.

3. METHODOLOGY

Research in the field of CPD approaches has also taken shape in the direction of literature reviews. For example Mkhwanazi (2014) produced a synthesis of literature on how teacher professional learning has been conceptualised and studied since the inception of educational reforms in the post-apartheid South Africa. The synthesis concludes that there have been remarkable efforts to engage teachers in professional learning and that there are shifts in policy frameworks from individual learning to collaborative learning. Mokhele (2014) also did a critical review on what constitutes 'best practices' in professional development by drawing on consensual voices and calls from literature. The synthesis focused on the form of activities that comprise professional development, duration and core features. Similarly, this paper is a literature study focusing on CPD approaches that promote successful practice of inquiry-based laboratory work in school science. The literature study

entailed searching data sources including books, websites and electronic data bases such as Google scholar, EBSCOHost and ERIC. This literature study contributes to efforts aimed at successful and widespread practices of inquiry-based laboratory work in school science.

3.1 Teacher professional development in science education

While on one side there is emphasis that professional development efforts should target teacher mastery of science content, the other side points out that this is not sufficient (Timperley, 2008). Achieving teacher mastery of content is just winning part of the battle because ultimately teacher development exercises should translate in improved learner achievement (Loucks-Horsley *et al.*, 2010). Kriek and Grayson (2009) attribute the state of science education characterised by poor achievement to teachers' limited content knowledge, ineffective teaching practices and unprofessional attitudes. They propose a holistic professional development model which addresses these issues and incorporates such as elements teacher collaboration. Currently, efforts in teacher professional development in South Africa mainly respond to the introduction of a number of new curricula that have been rolled out since the dawn of democracy in 1994 (Mkhanazi, 2014; Ono & Ferreira, 2010). Ono and Ferreira (2010) mention that the South African Department of Education utilised the Cascade model of teacher development which entails conducting the training in stages through training the trainer. For example specialists and experts train a small group of teachers who in turn will train teachers. This method has strengths in that it is cost effective and reaches participants in a short time (*ibid*). This approach is important with regard to delivering information about a new curriculum and other important aspects, such as methods for organising assessment portfolio of learners' work (Dass & Yager, 2009). However, it has been reported to be ineffective when it comes to changing teachers' instructional practices that significantly translate to the enhancement of student learning (Rout & Behera, 2014). Science education reform drives such as those embodying inquiry-based teaching and learning strategies cannot be accomplished by merely making the curriculum available, introducing new curricular materials and providing technological teaching aids in the classrooms (Dass & Yager, 2009; Rodrigues, 2005). Internationally, it is widely acknowledged that a considerable number of science teachers experience little or no professional development (Fraser-Abder, 2013; Rodrigues, 2005). Most of the professional development exercises are structured as short term conferences and workshops with teachers receiving lectures (Bilbao *et al.*, 2013; Rodrigues, 2005). The underlying assumption of the traditional methods of conducting professional development, as pointed out by Bilbao *et al.* (2013), is that teachers are viewed as technicians who should merely be equipped with skills to use generalised teaching strategies. Regrettably one of the situations resulting from the acquisition of generalised teaching strategies by teachers is the prevalence of textbook-centred pedagogy in science education (Kumar & Subramaniam, 2012).

3.2 Teacher professional development for inquiry-based laboratory work in science

Williams (2007) attributes barriers to the successful implementation of inquiry in science partly to factors that are out of the teachers' direct control. These factors include mandatory assessment modes that emphasise too much content coverage and factual recall of information (Rodrigues, 2005; Williams, 2007). Some of the factors stem from the socio-economic status, home and community (Timperley, 2008). However, teachers can directly control some of the factors that stand in the way of successful practice of inquiry. These factors include their gain of content knowledge, effective teaching approaches and development of professional attitudes (Kriek & Grayson, 2009). A parallel can be drawn between SA and the USA on the state of science education. Recently, there have been concerns to close the learner achievement gaps in mathematics and science if the TIMSS reports are anything to go by in both countries. In both SA and the USA the learner achievement gaps in mathematics and science can be characterised along racial lines and are clearly divided between rich and poor (Loucks-Horsley *et al.*, 2010; Reddy *et al.*, 2012; Spaul, 2013). In South Africa the availability of resources and infrastructure such as science laboratories and equipment is not

uniform across the different school contextual settings currently in existence (Government Gazette, 2010). The abolishment of an education system divided along racial lines (Selod & Zenou, 2003) has seen the emergence of a multi-tiered education system defined by school contextual settings such as African township and rural schools attended largely by African learners and learners from former Model C, former Indian, former Coloured and private schools with multiracial learner enrolments. Findings from a study taken to the different contextual settings on the practices of inquiry-based laboratory work in school physical sciences (Tsakeni, 2014), reveal that resources in the form of science laboratories are still concentrated in the contexts that previously benefited most from the political system of the pre-democracy era. Such is the case with the former Model C schools that, in the pre-democracy system were initially reserved for Whites. Some African schools, twenty years after the dawn of democracy, still teach science without a single science laboratory in the school while former Model C schools with similar learner enrolments have four science laboratories built during the apartheid era (*ibid*). However, the study findings reveal that the way teachers facilitated inquiry-based laboratory work could not be associated with the school contextual settings that they find themselves in. How teachers facilitated inquiry during practical work were influenced more by the manifestation and negotiation of their teacher professional identity traits in the given school contexts (Tsakeni, 2014) than the contextual setting of the school. Teachers can take ownership of and be responsible for their skills and knowledge gain in terms of subject content, inquiry-based teaching and learning strategies as well as attitudes and beliefs in science education. Hence the aim of this research study to search for teacher learning approaches that focus on their development in the practice of inquiry-based laboratory work in school science.

3.3 Forms of collaborative professional development

In the wake of the challenges experienced in implementing inquiry-based laboratory work in school science, the literature review was conducted in an effort to find and suggest approaches that seek to promote the wide practice of IBLW based on the assumptions underlying CPD. First, well-structured professional development programmes rooted in the learning theories which are guided by constructivism are reported to bring about the desired outcomes in teacher learning and ultimately improved learner achievement (Kempen & Steyn, 2015). Gulamhussein (2013, p. 24) says that 'Research suggest that there is an exceptionally strong relationship between communal learning, collegiality and collective action (key aspects of professional learning communities) and changes in teacher practice and increases in student learning'. Second, there should be an alignment between the learning theories used for teacher learning during professional development exercises and the teaching and learning methods they are expected to use in the classrooms (Gulamhussein, 2013). These learning and teaching strategies have inquiry as part of their embodiment according to stipulations in most national curricula (Department of Education, 2011; Hofstein & Lunetta, 2004). Dass and Yager (2009) point out that professional development should emphasise the shift from learning science by lecture and reading to learning science through investigation and inquiry. Accordingly, inquiry should be incorporated into teacher learning (*ibid*). This literature study has elicited some forms of collaborative professional development that are congruent with Vygotsky's theory of co-constructivism. However, it is critical that science teachers should be regarded as peers with close levels of cognitive development to ensure active involvement by all parties in the construction of knowledge on the practice of inquiry-based laboratory work. The use of external specialists, although important, usually results in discontinuous and short term development opportunities for teachers. Another pitfall is that the resulting professional development exercises will be in the form of lectures where the teachers are passive receivers of information most of the time. In SA, however, the organisation of schools in clusters provides an environment suitable for collaboration among teachers. Jita and Mokhele (2014) state that teachers who face challenges in content knowledge may seek help from colleagues in their clusters. Drawing from my years of teaching in the North West, clusters or group of clusters provided a platform for teachers to set common papers and discuss question papers and memoranda. The Kumar and Subramariam (2012)

says that teacher activities during CPD may include analysing textbooks, questions and student responses. Groups of clusters would also meet at a centre to mark learners' scripts for common examinations such as the mid-year and the trial examinations. Clusters would jointly organise examination preparation programmes for learners over weekends and vacations. Learners would have an opportunity to work with learners from other schools as well as be taught by teachers from other schools. The sharing of resource and facilities was also common within clusters. Teachers could make use of the already existing school cluster systems to engage in CPD in the practice of inquiry-based laboratory work in school science. Four forms of CPD aimed at promoting the practice and incorporation of inquiry, particularly for laboratory work are discussed below.

3.3.1 Teacher design teams

In teacher design teams, teachers work together to redesign and design curriculum and curriculum material (Kafyulilo, 2013; Waddoups *et al.*, 2004). The writer on the Pathway (2015) website asserts that for the successful practice of inquiry-based science education teachers have to possess specific competencies to match the inquiry-focused lesson with the existing topics, methods and materials. Although some curriculum statements may come with prescribed experiments such as the CAPS syllabus (Department of Basic Education, 2011), teachers still need to make meaning out of them and adapt them to their contextual settings. In a study conducted to establish inquiry-based laboratory work practices in school physical sciences (Tsakeni, 2014) some teachers perceived the prescribed experiments as meant for verification since content was taught to learners first. Therefore, they may need to restructure the activities so that they present learners with maximum opportunities to practice inquiry. Teachers also need to design other experiments and practical activities to augment the prescribed activities as they work to integrate inquiry in the process of teaching and learning. Teachers could support each other by working together in designing experiments and practical work activities that provide inquiry opportunities for learners.

3.3.2 Lesson Study

Lesson study as a form of CPD has the strength of being school-based (Tindi *et al.*, 2009). Japan is reported as one of the first countries to widely endorse, institutionalise and practice lesson study as a form of CPD (Kriek & Grayson, 2004; Kriek & Grayson, 2009; Ono & Ferreira, 2010). Lesson study has also been reported to have been endorsed in the USA. However, in other parts of the world such as Southern Africa, the feasibility of lesson study is still a subject under discussion and manifests as isolated pockets of innovation in the form of research projects. A few examples of such projects are the Mpumalanga Secondary Science Initiative MSSI (1999-2006) in South Africa (Jita & Mokhele, 2014; Mokhele & Jita, 2012; Ono & Ferreira, 2010) and the development of a teaching skills book by Tindi *et al.* (2009) in Zambia, detailing elements of a good lesson based on experiences of a school-based CPD programme through lesson study among others. In lesson study a lesson is planned by a group of teachers (Pektas, 2014). This lesson is then taught to learners while the other teachers are observing (Lewis, 2002; Saito *et al.*, 2006). The lesson is discussed, refined and documented (Lewis, 2000). This approach to CPD could be applied to the practice of inquiry-based laboratory work which has been reported to be fraught with challenges (Hofstein, 2004; McDonnell *et al.*, 2007). The idea of planning the inquiry activities together, observing the practical activities being facilitated for learners, discussing, refining and documenting the lessons present opportunities for the learning of inquiry-based laboratory work as a scientific concept, a teaching and learning strategy as well as a guiding philosophy in science by teachers. All science teachers in the school can participate in the lesson study group because inquiry-based laboratory work is a common teaching and learning strategy in science education. Lesson study is one way of embedding professional development in the teaching practice. It is school based and addresses both teacher and learner needs in context (Lewis *et al.*, 2004; Ahearn, 2011). As teachers co-construct the knowledge and ideas to promote inquiry, they take ownership of the skills and knowledge in the practice of inquiry.

3.3.3 Communities of inquiry about teaching

Shea *et al.* (2010) propound that a community of inquiry is a learning framework that is hinged on the construction of knowledge. Accordingly, teachers are encouraged to engage in inquiry activities as communities in order to generate knowledge to improve their practices (Bilbao *et al.*, 2013; Harlen & Allende, 2008). In this form of CPD teachers may be asked to compile reports on their practice which they will share with other teachers and generate discussions. In a model described by Doppelt *et al.* (2009), named, content-based collaborative inquiry (CBCI), teachers worked to make meaning of how learners think and understand particular subjects. They discussed learners' understanding, collected and analysed data, and shared the results with the aim of collaboratively coming up with recommendations to inform policy. In this way science teachers could engage in research in the practice of inquiry-based laboratory work and add a voice from a hands-on perspective. This ensures constructive teacher reflection at best to engage learners in inquiry during laboratory activities.

3.3.4 Information and communications technology (ICT) supported collaborations

Teachers can develop a sense of community and collegiality through online communities. Garrison and Arbaugh (2007) posit that camaraderie can be developed among members of a community through online interactions. It has been established that facilitation and direction of cognitive processes that result in construction of meaning through sustained reflection and interaction are achieved in online communities. The integration and incorporation of information and communications technology (ICT) such as online communities in the professional development exercises can facilitate collaboration among members of a community who may be geographically separated. Boitshwarelo (2009) explored the integration of technology in CPD by creating Biology Teachers Online. Teachers carried out exemplar biology practical work sessions and together reflected on them through email correspondence. Teachers were able to discuss issues such as changing trends in curriculum, instructional practices and practical work. The practice of inquiry-based laboratory work could benefit immensely from this kind of teacher collaboration. It connects different stakeholders such as trainers, specialists and scientists to engage with teachers in their collaboration efforts. Videos of teacher-student interactions during science experiments and laboratory sessions could be uploaded online for teachers to analyse and discuss (Kumar & Subramaniam, 2012).

4. CONCLUSION AND RECOMMENDATIONS

This paper proposes ways of overcoming the ineffective implementation of inquiry-based laboratory work in school in the wake of curricula stipulations to incorporate inquiry. The paper discussed four approaches to CPD that ensure that teacher learning is achieved through their active participation in the construction knowledge of inquiry and knowledge of inquiry teaching and learning in school science. The approaches to CPD are firmly grounded in Vygotsky's theory of co-constructivism. Teacher designer teams, lesson study, communities of inquiry and ICT-supported collaborations have been put forward as approaches in teacher development for inquiry practice as they are directly intertwined with classroom practice. Accordingly, the impact of teacher learning will have an influence on student learning. These approaches in professional learning ascertain teachers' prior knowledge (Loucks-Horsley *et al.*, 2010) and build on it by recognising the richness of teacher thinking as a useful resource (Rodrigues, 2005). The approaches are task-embedded, school-based and utilise existing structures of school clustering hence initiation thereof can be done by the teachers themselves. Their continuity and sustainability do not entirely depend on external support from specialists and sponsors. In the interest of promoting inquiry-based laboratory work in school science this paper makes a few recommendations. First, deliberate efforts should be made for IBLW to inform CPD programmes in school science. IBLW practice should be made an area of professional development focus. Second, the CPD approaches should be integrated into the whole school improvement programmes so that they receive the much needed support in the form of resources



and time allocation. Third, CPD efforts to promote IBLW in school science should also enlist the support of specialists such as subject advisors, researchers, teacher educators, scientists and sponsors who can provide laboratory equipment and materials to under-resourced schools.

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