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**RESEARCH
IN BASIC
EDUCATION**
IN SOUTH AFRICA

CHAPTER 7

Science teacher professional development in post-apartheid South Africa: A systematic review of the literature on basic education

Elaosi Vhurumuku

Email: elaosi.vhurumuku@wits.ac.za

School of Education, University of the Witwatersrand

Abstract

This systematic review analysed and synthesised the research done on effective science teacher professional development (PD) in post-apartheid South Africa, for the period 1994 to 2019, focusing on basic education. It investigated the efficacy of professional development models, with the aim of identifying models which positively impacted on science teachers and had the potential to improve teaching effectiveness. It also explored the issue of how South African researchers and education practioners evaluated the effectiveness of PD. Twenty articles were selected for analysis from electronic search of data bases. The findings reveal that 13 (65%) of the 20 analysed studies concluded that PD had a positive impact on participating teachers. Seven studies (35%) were either inconclusive or concluded that PD was ineffective. While researchers and education practioners have 'successfully' used a variety of PD models, the training and cascading models were the most popular. The results also show that, for all the reviewed studies, the evaluations of the effectiveness of PD only focused on what happened to the teacher and completely ignored determining the impact on students' learning outcomes, performance and achievement. It is recommended that future evaluations of science teacher PD efforts should take into account the effect or impact of the PD on students' learning outcomes, performance and achievement.

Keywords: science teacher, professional development, teaching effectiveness, evaluation, student learning

Introduction

Globally, it is now generally accepted that the success of educational programmes and reform initiatives largely hinges on the quality and effectiveness of teachers. It is also unanimously accepted that student learning and achievement can only be improved if teachers have the requisite knowledge and pedagogical skills, which enable them to be effective practioners. There is an underlying assumption that outcomes for students can be improved through effective professional development of teachers (Doig & Groves, 2011; Garet, Porter & Desimone et al., 2001; Guskey, 2002; Darling-Hammond, Hyler, & Gardner, 2017). Professional development

of teachers is often synonymous or conflated with teacher professional learning or in-service education or staff development. Grosemans, Boon, Verclairen et al. (2015) argue that professional development for teachers is necessary because society is constantly changing; meaning that teachers also have to change and/or reform their teaching knowledge, practices, skills, attitudes and beliefs in order to continue transforming the students' learning outcomes. In many parts of the world the changing socio-economic, political, ideological contexts and professional environments have resulted in unprecedented financial investment in effective teacher professional development. Effective teacher professional development (PD) is about involving teachers in learning that results in them changing and/or reforming their teaching practices, skills, attitudes and beliefs so as to transform the learning outcomes of students (Darling-Hammond et al., 2017; Guskey, 2002).

While there appears to be agreement that teacher PD can result in improved teaching effectiveness, there is dissensus around issues of how effective professional development should be done and what should be its features. These contestations are made more complicated by the lack of a generally agreed-upon understanding of what it is which should be called effective teaching (Goe, Bell, & Little, 2008; Patrick & Smart, 1996). For more than fifty years, the landscape of research on teacher professional development and effective teaching has been dominated by the questions: What is it that should constitute effective teacher professional development? Which models of professional development result in improved teaching practices? How can the effectiveness of teacher professional development be determined? What is effective teaching and how can it be characterised? And does teacher professional development improve teacher effectiveness?

In science education, research focusing on investigating the relationship between teacher professional development and instructional effectiveness has been going on for almost eight decades (see, Capps, Crawford, & Constas, 2012.; Yoon et al., 2007; Guskey, 2010; Guskey & Huberman, 1995; Thair & Treagust, 2003; Villegas-Reimers, 2003; Van Veen, Zwart, & Meirink, 2012; Buczynski & Hansen, 2010; Lumpe, Czerniak, Haney et al., 2012; DeBoer, 1991; Wilson, 2013). This research can be stranded into several foci, including: the effect of professional development (PD) programmes or interventions on science teachers' teaching practices (e.g. Supovitz & Turner, 2000; Capps, Crawford, & Constas, 2012); examining the effect of teacher professional development models on teacher knowledge and practices (e.g. Jimoyiannis, 2010; Heller, Daehler, & Wong et al., 2012); investigating the effectiveness of professionally developed teachers in implementing new or reformed science curricula and programmes (e.g. Wilson, 2013; Penuel, Fishman, & Yamaguchi et al., 2007); the effect of professional development on teachers' self-efficacy, attitudes and beliefs (e.g. Lumpe, Czerniak, & Haney et al., 2012; Carleton, Fitch, & Krockover, 2007; Tosun, 2000); factors that can facilitate or impede teacher engagement with PD (Kervin, 2007; Opfer &

Pedder, 2011); and the effect of professional development on teachers' pedagogical content knowledge (PCK) (e.g. Van Driel & Berry, 2012; Appleton, 2008).

Within this realm, the terrain of discourse has been dominated by contestations concerning how to evaluate the effectiveness of professional development. For example, it has been argued that the evaluation of the effectiveness of PD should be based not on determinations and measurements of what happens to teachers, e.g. improvements in their content and pedagogical knowledge, etc.; but focus more on student learning outcomes as the underlying endeavour (Earley & Porritt, 2014; Guskey, 2002).

Given the arguments surrounding teacher professional development and its effectiveness, the current systematic review focuses on this topic. It follows the footsteps of Guskey and Yoon (2009), who carried out a synthesis of the research literature focusing on the relationship between teacher professional development and student achievement as an indicator of PD effectiveness. In interrogating this issue, their review addressed questions about: the relationship between professional development and student learning; the validity of evidence justifying that relationship; and what should be called truly effective professional development? To date, in addition to this work, several systematic reviews focusing on effective professional development of teachers have been undertaken internationally (see for example, Vangrieken, Meredith, & Packer et al., 2017; Yoon, Duncan, & Lee, 2007; Trede, Macklin, & Bridges, 2012; Steinert, Mann, & Centeno et al., 2006; Luneta, 2012). None of these reviews, however, explicitly focuses on analysing and synthesising the research on effective professional development of science teachers. The systematic review being presented in this chapter is the first to do so. In addition, the current review is the first on this topic to be done in South Africa focusing on basic education.

Purpose of the review

This review's major focus is exploring, analysing and synthesising the research literature on effective science teacher professional development and its evaluation in post-apartheid South Africa. Only the research done in basic education in South Africa between the years 1994 and 2019 is considered. For South Africa, the demise of apartheid in 1994 brought about political, economic and social changes, which were accompanied by changes in the education system (Vandeyar & Killen, 2007) including transformation of school science curricula. School science curricula changes brought about a necessity for teacher professional development. It is in the light of this background that the focus of the current review was limited to research done during and after 1994.

In science education, systematic reviews are increasingly being used to explicitly answer specific questions based on cumulated research evidence. Polanin, Maynard

and Dell (2017) argue that, systematic analysis, appraisal and summarisation of burgeoning research literature can lead to the generation of new knowledge as well as inform policy and practice. This supports Hargreaves (1996), who suggests that in similar fashion to what is done in medical research, systematic reviews can be used in educational research to contribute to theory and practice through answering questions about what works and what does not.

As indicated, the major goal of this review is to determine the efficacy of professional development models in improving science teachers' classroom effectiveness as determined by student learning outcomes. Through this determination, and focusing on research in basic education in post-apartheid South Africa, the review attends to answering questions about what science teacher professional development models have been effective and how the effectiveness of PD has been measured. The research questions that guided this review were:

- Which professional development models have resulted in improving teaching effectiveness for science teachers?
- How have South African researchers determined the effectiveness of science teacher professional development?

It is important to point out that, in the context of this review, basic education refers to education in primary and secondary schools as well as tertiary education and vocational training. This means the search for literature on effective teacher professional development covered these levels of the South African education system. The review's focus was on research done on practising, in-service and pre-service science teachers including lecturers and professors involved in science teacher education. The focus was on school science education and tertiary science teacher education. Science teaching was taken to encompass the teaching of Natural Science, Physical Science, Chemistry, Physics and Life Sciences/Biology at primary and secondary schools as well as tertiary and vocational science teacher education. Teacher professional development and teaching effectiveness in such fields as medicine, engineering and environmental science, were excluded from the review.

Given the focus of this review, it is fitting to briefly examine some theoretical and conceptual tenets on effective professional development and teaching effectiveness.

Effective teacher professional development

Rationales for teacher professional development

In the present epoch of the Anthropocene, the demands made on both education and teachers have made effective teacher professional development a major focus of systemic reform initiatives around the globe (Garet, Porter, & Desimone et al., 2001; Bhattacharya, Roehrig, Kern, & Howard, 2014). The political, social,

economic and environmental challenges society is facing in the Anthropocene, has generated new expectations of teachers. Anthropogenic challenges include such issues as: climate change, global warming, the greenhouse effect, deforestation, drug abuse, environmental degradation, species extinction, sustainable use of natural resources, democratisation, and HIV/AIDS.

While it is true to say that science teacher professional development should desirably be a continuous and lifelong endeavour (Ryan, 2003; Nicholls, 2000), the reality is that in most cases teacher PD has largely been driven and necessitated as a reaction to challenges and changes and/or reforms in the educational milieu. These include PD of teachers as a response to: science education curriculum changes, reforms and innovations – with PD aimed at capacitating teachers to implement new or reformed curricula, e. g. incorporating new subjects and/or new content requiring new social and technical competencies (Wilson, 2013; Penuel, Fishman, & Yamaguchi et al., 2007); efforts to mitigate anthropogenic challenges (Hestness, McDonald, & Breslyn et al., 2014); efforts to remediate identified teacher deficiencies e.g. poor subject knowledge mastery (Bayar, 2014); for certification of unqualified and qualified teachers (Ono & Ferreira, 2010); and advancements in information and communication technologies, which lead to the introduction of new technology-based teaching approaches and strategies (Mouza, 2002; Brinkerhoff, 2006).

In addition to these factors science teacher PD has also been driven by efforts to demonstrate the efficacy of underpinning theoretical models, orientations and paradigms. Examples of this include: research focusing on professional development of teachers' pedagogical content knowledge (PCK) (Van Driel & Berry, 2012; Doering, Veletsianos, & Scharber et al., 2009), teacher professional development as part of action research (McNiff, 2010), and demonstrating the role that teacher communities (TCs) can play in effective professional development (Boone, 2010; Vangrieken, Meredith & Packer et al., 2017). Generally, irrespective of the rationale for PD, its major goal is bringing about changes in the knowledge, skills, attitudes, beliefs and values of teachers, which in turn are assumed to change or improve classroom practices, resulting in the logical consequence of change or improvement in the learning outcomes for students. As already noted, teacher professional development is associated with teacher learning which brings about change in the classroom (Guskey, 2003; Garet, Porter, & Desimone et al., 2001).

Models of teacher professional development

Teacher professional development can be organised and structured in a variety of ways based on a wide spectrum of rationales. Bayar (2014) categorises teacher professional development into traditional and non-traditional. Traditional teacher professional development is organised and structured around short workshops (one day, one week or one month), conferences and seminars. This type of PD

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has been castigated by many researchers for being too brief, disjointed and out of tandem with the state of reality in the classrooms (Ono & Ferreira, 2010). Non-traditional teacher professional development is about organising programmes and/or activities, which include mentoring, coaching, peer collaboration, observation and reflections, participation in a network of teachers, clusters of teachers, individual or collaborative research focusing on a topic of professional interest, reading professional literature, engaging in informal dialogue with peers on how to improve teaching, and participation in teacher communities of practice (TCP).

Table 7.1 *Models of continuous professional development*

Model	Characteristics and theoretical underpinnings	Delivery actions and activities
Training Model	<ul style="list-style-type: none"> -skills-based, technocratic view of teaching -centralized and transmissive -focus on introducing new knowledge/skills -teacher must achieve pre-determined standards 	<ul style="list-style-type: none"> -Expert delivers knowledge and skills to teacher -Delivery at the institution or outside sites
Award-bearing Model	<ul style="list-style-type: none"> -emphasises, the completion of award-bearing programmes or courses of study -focuses on classroom practice 	<ul style="list-style-type: none"> -teacher attends or does courses which lead to recognition or accreditation by, for example, professional bodies
Deficit Model	<ul style="list-style-type: none"> -aimed at addressing perceived deficits in teacher performance through remedial action -linked to performance management 	<ul style="list-style-type: none"> -teacher attends a course or program focusing on remediating perceived weaknesses
Cascade Model	<ul style="list-style-type: none"> -teachers attending 'training events' and then cascading or disseminating the information to colleagues -training-the-trainer to ensure that the message flows down from experts and specialists -focus on developing knowledge and skills -technicist view of teaching, where skills and knowledge are given priority over attitudes and values 	<ul style="list-style-type: none"> -teachers attend workshops, courses and training events and then cascade or disseminate information learnt to colleagues
Standards-based Model	<ul style="list-style-type: none"> -based on behaviourist perspectives of teaching and learning, focusing on the competence of individual teachers and resultant rewards -emphasis on the 'professional actions', as a measure of achievement of standards or competencies -standards and competencies to be achieved are centrally determined 	<ul style="list-style-type: none"> -teacher achievement of standards or competencies are externally assessed and evaluated

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Model	Characteristics and theoretical underpinnings	Delivery actions and activities
Coaching/ Mentoring Model	<ul style="list-style-type: none"> -experienced teacher mentors or coaches the novice teacher -novice does apprenticeship under tutelage of mentor - can be hierarchical or collegial - can be based on transmission or transformative view of learning about teaching 	-experienced teacher mentors or coaches the novice teacher
Community of Practice Model	<ul style="list-style-type: none"> -involves two or more teachers who form a professional community to learn about practice -based on social theory of learning -teachers involved in: mutual engagement, understanding and tuning [their] enterprise; and developing repertoire, styles and discourses 	-teachers participate in learning communities and improve their knowledge and skills
Action Research Model	<ul style="list-style-type: none"> -main aim is practitioner development and transformation -teachers acting as researchers critically examine their practices with a view to improving the quality of teaching -teachers' understanding of the situation, as well as the practice, within the situation 	-teachers research on their practices to improve teaching and learning
Transformative Model	<ul style="list-style-type: none"> -combination of practices and conditions -integration of the range of models described above -a tenacious balance of power relations and accommodation of stakeholder interests 	-uses approaches and actions in the other eight models

A summary based on Kennedy A. (2005). Models of Continuing Professional Development: a framework for analysis. *Journal of In-service Education*, Volume 31, Number 2, pp. 236-247)

Within these domains teacher PD can be continuous or non-continuous. Continuous teacher professional development (CTPD) is ongoing and based on the principle that teachers need to make learning about teaching a lifelong endeavour. It is about unremittingly enhancing the knowledge and skills of teachers through ongoing orientation, training, support, reflection and review (Coetzer, 2001; Kennedy, 2005). With non-continuous PD, the orientation, training and support is intermittently done, sometimes only once in the working life of the teacher. This type of PD is usually done as a direct response to factors in the educational milieu.

It is argued that, to a very large extent, the success and effectiveness of teacher PD depends on how it is organised, structured and implemented. In the literature several descriptions and classifications of continuous professional development (CPD) models are found (see for example, Dede, 2006; Heller, Daehler, & Wong et al., 2012; Kennedy, 2005). For this review, the description and classification by Kennedy (2005) is used as a lens for the analysis mainly because of its simplicity and comprehensiveness. According to Kennedy (2005) CPD can be done using

models which fall into nine broad categories. While the models are comprehensive, they are neither necessarily exhaustive nor exclusive. Table 7.1 shows a summary of these models.

Evaluating the effectiveness of teacher professional development

Darling-Hammond, Hyler and Gardner (2017) describe effective PD as one which: focuses on content subject matter and pedagogy; incorporates active learning; supports teacher collaboration; uses models of effective practice; provides coaching and expert support; offers feedback and reflection; and is of sustained duration. In addition to this, it is argued that an effective PD activity should: have an establishing clarity of its purpose at the outset; include a clear focus on student learning outcomes; specify its focus and goal with clear timescales; have an understanding of the current practice at the start of the activity/project; make participants' feel ownership of the activity; and have a clear understanding of how to evaluate the impact (Earley & Porritt, 2014).

Nonetheless, it has been pointed out that there is dissensus around what it is that should be done in evaluating the effectiveness of teacher professional development. This is pertinent because there are many models of evaluating PD and its effectiveness – all of them proclaiming truth (see for example, King, 2014; Earley & Porritt, 2014; Bubb, 2013). Earley and Porritt (2014) posit that much of the evaluation of PD done by school leaders, practitioners, policy-makers and researchers is simplistic, impressionistic and untrustworthy as it is based on simple measures (e.g. post-event evaluation forms or a 'happy sheet', questionnaires and interviews). They suggest that the evaluation of the effectiveness of PD should be based on elements focusing on the intended outcomes and the impact on student learning. This supports Pedder, Opfer and McCormick et al. (2010) who argue that evaluation of PD should focus on adequately specified learning outcomes for teachers, which must be made explicit from the beginning. These outcomes must be sufficiently linked to student learning outcomes, school improvement and teacher self-evaluations. In essence, the determination of the effectiveness of PD is about gathering asserted or substantiated evidence on these aspects, in order to precisely ascertain the impact of the PD process (Earley & Porritt, 2014).

Guskey (2002) contends that the focus of evaluating the effectiveness of PD should be on learning outcomes for students. However, she flags some pillars on which evaluation of the impact of PD should be built. According to Guskey (2002) the impact of PD can be evaluated through determining: its impact on students' learning outcomes (effect on experience, attainment and achievement of students); its impact on participants' (teachers') learning; its impact on participants' (teachers') use of new knowledge and skills; the participants' (teachers') own evaluations and reflections of the PD; and whether the organisation (e.g. the school) changes in terms of practices and support of the teaching and learning process. Building on

Guskey's (2002) and other works (for example, Bubb & Earley, 2010; Ofsted, 2010; Bubb, 2013), Earley and Porritt (2014) argue that the key issues in evaluating the impact and hence the effectiveness of PD is to know whether PD has made a difference to teachers, students and the organisation (precisely the school). While they accept that in evaluating the effect of PD, it is important to determine the changes and improvements in teachers' subject matter knowledge, planning, pedagogy, teaching skills, attitudes, beliefs and values; they emphasise that student learning outcomes should be at the core of PD evaluation. As they correctly articulate, the purpose of professional development should from the outset be to improve the learning for students. Consequently, evaluation of the effectiveness of PD should be focused on determining whether there is a difference between the performances of students before teachers underwent PD and after they have gone through a PD activity or programme.

Teaching effectiveness

As previously noted, it is generally accepted that the most critical determinant of student performance and achievement is the quality or effectiveness of the teacher (Darling-Hammond, 2000; Muijs & Reynolds, 2001). Although there is this unanimity, there are gruesome quarrels around the issues of: what it is that should be called effective teaching, and how teaching effectiveness should be evaluated or measured. Coggshall (2007) asserts that these ponderous but divergent eruditions arise because of the existence of a multiplicity of perspectives on what makes good teaching and how to gauge it in a valid way. The diversity of perspectives is an inevitable consequence of the existence of a surplus of stakeholders in education. These stakeholders include politicians, policy makers, parents, teachers, students, and researchers. Each of these interested parties advocates for different conceptions of effective teaching and its evaluation based on political, ideological, socio-economic, and paradigmatic orientations and aspirations.

Darling-Hammond (2010) describes an effective teacher as one who is: generally intelligent and can organise, explain and communicate ideas, has strong pedagogical content knowledge, shows an understanding of learners and their learning and can cater for differentiation, and adapt and modify his/her teaching to cater for student needs. From the literature (see for example, Sammons, 2006; Pretorius, 2012; Muijs & Reynolds, 2001) effective teaching has also been pronounced as involving: catering for differentiation in the classroom; being able to deliver lessons with clarity; keeping students motivated; setting high standards for student achievement; showing good classroom management skills; being able to appropriately sequence the content; showing mastery of questioning skills and techniques; ability to plan and use teaching and learning resources appropriately;

ability to monitor student understanding formatively and summatively; and working collaboratively with peers. All these aspects focus only on the teacher.

Several scholars, however, argue that it is problematic to determine teaching effectiveness by solely focusing on the teacher or only on student learning and achievement as measured by standardised test scores (e.g. Fenstermacher & Richardson, 2005; Goe, Bell & Little, 2008). They contend that the effectiveness of the teacher depends on a matrix of variables, which include: the quality of the student, availability of teaching and learning resources, the physical learning environment, administrative support, student motivation and the nature of the curriculum. Based on this, Goe, Bell and Little (2008), advocate for a consensually arrived at definition of teacher effectiveness, which is comprehensive and a composite of these factors. They recommend that the determination of teaching effectiveness should be based on a weighted fusion of the following: classroom observation of the teacher; evaluation of the teacher by peers including school principals; use of instructional artifacts which are structured protocols used to analyse such things as the quality of instruction, lesson plans, teacher assignments and tests, and students' written work; a teaching portfolio which documents teaching behaviours and responsibilities; teacher self-report measures; student evaluations of the teacher; and a value-added model, which is a calculation of the teacher's contribution to student achievement as measured by test scores.

Method

Literature search and selection procedure

The literature search team for this review consisted of the author and two research assistants. Bearman, Smith and Carbone et al. (2012) suggest that in order for systematic reviews to answer the targeted research questions, they need to use explicit inclusion and exclusion benchmarks, transparent search strategies, clear data analyses procedures as well as synthesise all the available evidence. The literature searches and selection procedure adapted was based on a blend of the approaches described by Van Lankveld, Schoonenboom and Volman et al. (2017), Bennett et al. (2005) and Bearman (2012). A synopsis of this adoption summates into the sequence shown in Figure 7.1.

First, the study title was formulated and research questions identified. Second, inclusion and exclusion criteria were formulated. Inclusion or exclusion of articles for review was based on the following criteria:

Teacher professional development focus: Only empirical research articles that focused on teacher professional development in basic education at the primary and secondary schools as well as tertiary teacher education and vocational teacher training were to be included.

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Science teacher professional development: Only empirical research articles that focused on science teacher professional development in basic education were considered. Articles also focusing on the professional development of Natural Science, Physical Science, Chemistry, Physics and Life Sciences/Biology teachers in basic education were considered. Articles focusing solely on teacher professional development in other disciplines, such as environmental science, technology, engineering, medicine and mathematics were excluded. Articles which involved science and mathematics teachers were included.

Geographical location of the research: Only empirical studies, quantitative or qualitative, done in South Africa were considered for selection.

Article publication period: Only empirical research articles published in referred journals and conference proceedings between 1994 and 2019 were considered.

Teaching effectiveness: Only articles that referred to determining the impact of PD on teachers' knowledge, skills, practices, beliefs, attitudes and values, teacher effectiveness/quality and/or the effectiveness of professional development were selected.

Third, based on the title and research questions, the following search phrases, terms and words were formulated and used alone or in combination: 'South Africa development of science teacher content knowledge', 'teacher professional development teaching effectiveness', 'South Africa science teacher professional development teaching effectiveness', 'South Africa science teacher professional development teacher quality', 'science teacher professional learning and effectiveness', 'teacher professional development', 'science teacher professional development', 'South Africa effectiveness of professional development', 'South Africa science teacher professional development', 'South Africa professional training teaching effectiveness', 'science teacher quality', 'in-service professional development science', 'in-service science teacher training South Africa', 'professional development basic education South Africa', 'physical science teaching South Africa', 'natural sciences teaching South Africa', 'Biology teaching South Africa', 'Life sciences teachers South Africa', 'Chemistry teaching professional development South Africa', 'Physics teaching professional development South Africa', and 'teacher development and effectiveness South Africa'.

Using these search phrases, terms and words, a search for potentially relevant articles was done using electronic searching. This included use of Google Scholar, extensive searches of all relevant education databases such as: ERIC, EBSCO, Academic Search Ultimate, Abstracts, WITS library bibliography databases, Ingenta and SCOPUS. The literature search looked for published work focusing on referred journals and conference proceedings, including online publications. Masters and Doctoral dissertations published online were not considered.

Fourth, screening and classification of studies was done applying the inclusion and exclusion criteria to identify potentially relevant studies. This stage also involved

looking at article titles and reading and coding abstracts. Fifth: full text reading and screening of articles applying inclusion and exclusion criteria. Sixth: in-depth reading of screened articles and summarisation of each study's work including study goal, theoretical framework, study design, data-collection methods and major findings. Seventh: Analysing the study findings to extract the key data from the studies and making decisions about answering the review questions regarding the impact and/or effectiveness of science teacher professional development and how the impact of PD and teaching effectiveness were determined.

Figure 7.1 *A summary of the literature search and selection procedure (Adapted from Van Lankveld, Schoonenboom & Volman et al., 2017; Bennett et al., 2005 & Bearman, 2012)*

Analysis and synthesis

In order to organise and interpret the literature, a descriptive and qualitative analysis and synthesis was done along the approaches followed by Van Lankveld, Schoonenboom and Volman et al. (2017) and Vangrieken, Meredith and Packer et al. (2017). This translated into a fusion of thematic (De Rijdt, Stes, & Van der Vleuten et al., 2013) and narrative analysis (Thomas & Harden, 2008). First the team members read and coded the abstracts in order to get the major themes of each article. They then discussed their coding. These resulted in the exclusion of some articles as they were adjudged not to meet the inclusion criteria, and were irrelevant to answering the review questions. Twenty articles were identified as relevant to answering the study questions.

Second, all the 20 screened and selected articles were read in-depth and the main study features summarised in an inventory. For each article the following characteristics were captured: Author(s); Article Title; Year of Publication; Journal/Book; Study aims/objectives/questions; Theoretical/conceptual framework; Research design; Sample characteristics; Professional development model used; Rationale for the PD; Method used to evaluate effectiveness of PD; Outcome of the PD; Method used to determine teaching effectiveness; Major findings; and Conclusion(s). The assignment of studies to PD models was guided by the description and classification by Kennedy (2005) (see Table 7.1). Each of the three members of the research team independently read the selected articles and produced an inventory. The team members then came together to review decisions, compare inventories and come to consensual agreement regarding the assignment of characteristics to a study. In this way the rigour, credibility, transferability, dependability, and confirmability of the data were assured (Maxwell, 1992). Third, an iterative comparison was made of the summarised results in order to check for regularities and patterns and determining whether the findings were relevant to answering the review questions (Van Lankveld, Schoonenboom, & Volman et al., 2017). Fourth, each of the articles was re-read in-depth in order to identify sections, paragraphs and lines which contained information related to answering the research questions for the review (Vangrieken, Meredith, & Packer et al., 2017). The following themes were used: Professional development model (research Question 1); Method of evaluating impact or effectiveness of PD (Research questions 1 and 2); Method of determining teaching effectiveness (Research question 2); measuring teacher competencies (Research questions 1 and 2); and determining student outcomes (Research questions 1 and 2).

Results

Overview of studies included in the review

Before addressing the research questions, which is done in the discussion section, it is fitting to give an overview of the studies included in this review. In doing so, key elements and characteristics essential for answering the research questions are teased out. In Table 7.2 the key features and characteristics of the studies analysed for this review are summarised, with the numbers of studies given. In addition to this table a description of the review results is given. This description captures the following aspects: the methodological approaches used in the studies – including the data collection and analysis procedures; an outline of the major rationale(s) for the undertaken professional developments; the types of PD models used; a narration of the approaches and strategies used to determine the effectiveness of the PD (i.e. how the impact or effectiveness of PD was evaluated); and the outcome(s) (major findings and conclusions) of the studies.

The methodological approaches used in the studies

In general, all the reviewed studies reported on the impact of professional development on the content and pedagogical knowledge, skills, practices, attitudes and beliefs of participating teachers. Of the twenty reviewed studies, twelve or 60% employed qualitative research methodology. Six studies (30%) utilised a combination of quantitative and qualitative methodology. Two studies (10%) were quantitative, with one of these utilising an experimental design. Three of the reviewed studies (Mavhunga & Rollnick, 2016; Pitjeng-Mosabala & Rollnick, 2018; Mavhunga & Rollnick, 2013) were PD interventions involving pre-service/ novice secondary school teachers. The rest of the studies involved practising primary and/or secondary school teachers. Across the studies the dominant methods of data collection are: using questionnaires, pre- and post-intervention questionnaires and interviews, teacher reflective journals, lesson observations and teacher self-evaluations.

Table 7.2 *A summary of the main features and characteristics of the reviewed studies*

Model	Methodological Approach(es)			Improve teachers' classroom practices	Study Rationales				Evaluation of the impact effectiveness of PD	Outcome (s) of PD			Summary of Major Finding (s)
	Qualitative	Quantitative	Mixed		Improve content and pedagogical knowledge	Skills to implement new science curricula	To demonstrate the efficacy of a PD model	Teacher focus		Student learning focus	Positive	Negative	
Cascade Model	4	1	1	6	2	0	2	6	0	3	1	2	Improvement in half the studies negative. and inconclusive for the other half
Training Model	3	0	3	3	4	0	0	6	0	4	1	1	Improvement in four studies negative, and inconclusive for two studies
Action Research Model	2	0	1	3	0	3	3	3	0	2	1	0	Positive and negative result
Community of Practice Model	2	0	0	2	0	0	2	2	0	1	0	1	Positive and inconclusive result
Coaching/ Mentoring Model	0	1	0	1	0	1	1	1	0	1	0	0	One positive result
Deficit Model	0	0	1	1	1	0	0	1	0	1	0	0	One positive result
Transformative Model	1	0	0	1	0	0	1	1	0	1	0	0	One positive result
Totals	12	2	6	20	7	4	9	20	0	13	3	4	

The rationales for professional development

Four major reasons or rationales flesh out as having been the drivers of the research. For some studies, more than one driver was identified. All the studies mention the need to improve teachers' classroom practices as a goal of PD. Within this recognition the need to change teachers' beliefs and attitudes is also acknowledged (e.g. Onwu & Mogari, 2004; Kriek & Grayson, 2009). One of the dominant motivations cited is the need to improve the quality of science teachers' content and pedagogical knowledge. Seven of the twenty reviewed articles give this reason as a justification for study. Examples of these include: Mavhunga and Rollnick (2016), Pitjeng-Mosabala and Rollnick (2018), and Mogari et al. (2016). For these studies, there is an inherent assumption that there is a deficit in the teachers' knowledge which needs addressing.

Four studies appear to have been driven by the necessity to equip teachers with the requisite knowledge and skills to implement new science curricula (see, Singh-Pillay & Samuel, 2017; Onwu & Mogari, 2004; Bantwini, 2009; Ono & Ferreira, 2010). Suffice to mention that post-apartheid South Africa has experienced three major waves of curriculum reform. First was the Curriculum 2005 (C2005), introduced in 1997, which became the Revised National Curriculum Statement (RNCS) in 2002. This was followed by the National Curriculum Statement (NCS) of 2007, and the current Curriculum and Assessment Policy Statements (CAPS), which was introduced in 2012. The studies by Onwu and Mogari (2004), Ono and Ferreira (2010) and Bantwini (2009), for example, were in response to challenges faced by teachers in implementing outcomes-based education, adopted after independence as part of decolonising education. They sought to equip teachers with the requisite content knowledge and skills to change their teaching ways in line with the Revised National Curriculum Statement (RNCS) introduced in 2002. The study by Singh-Pillay and Samuel (2017) focused on the implementation of all three curricula including the CAPS of 2012.

Nine of the twenty studies are categorised as having been motivated fully or in part by the desire to demonstrate the efficacy of a professional development model or try out a 'new' PD model (see, Aldridge, Fraser, & Sebela, 2004; Reed, Davis, & Nyabanyaba, 2002; Harvey, 1999; Mbowane, Rian de Villiers, & Braun, 2017; Mokhele, 2013; Jita & Mokhele, 2014; Ndlalane & Jita, 2009; Ono & Ferreira, 2010; Bantwini, 2009). Of these studies, three are attempts to show that action research is an effective approach to PD (Ono & Ferreira, 2010; Reed, Davis, & Nyabanyaba, 2002; Aldridge, Fraser, & Sebela, 2004). Two of the nine studies are efforts to use the teacher communities of practice (TCP) model to: improve teachers' PCK, resulting in changes in classroom practices (Ndlalane & Jita, 2009); and to alter the knowledge, beliefs and practices of teachers (Jita & Mokhele, 2014). One study (Mbowane, Rian de Villiers, & Braun, 2017) investigated the effect of teacher attendance of science fairs on their professional identity and

professional development, including their pedagogical knowledge and insight into inquiry-based learning approaches as well as topic-specific PCK. This was categorised as following the cascade model of PD since teachers who attended the fair were expected to disseminate information learnt to colleagues and to students (Kennedy, 2005).

Identified types of PD models

Overall, based on the descriptions and classification by Kennedy (2005), the reviewed studies were categorised as falling under the following PD models: Cascade Model-6 (30%); Training Model-6 (30 %); Action Research Model-3 (15%); Community of Practice Model-2 (10%); Deficit Model-1 (5%); Coaching/Mentoring Model-1 (5%); and Transformative Model-1 (5%). This categorisation was done using Kennedy's (2005) framework, irrespective of the fact that some of the studies made claims to implementing a new PD model (e.g. Kriek & Grayson, 2009; Mokhele, 2013; Jita & Mokhele, 2014). For example, Kriek and Grayson (2009) tried out what they call a Holistic Professional Development (HPD) model, in which the intervention started with a baseline study, and offered a developed, year-long Physics course that was taught through workshops and distance learning. Their study sample consisted of 12 teachers from rural schools in Limpopo Province. To evaluate the PD effectiveness of this model they analysed data from assignments, teachers' journal entries, pre- and post-tests, examination scripts, workshop evaluation forms, classroom observations and interviews. They concluded that the application of the HPD model resulted in improvements in content knowledge, teaching approaches, and professional attitudes of the participating teachers. However, when the HPD is carefully scrutinised it reveals features and characteristics of Kennedy's (2005) transformative model. This is so because a combination of practices and conditions as well as integration of at least two models is evident. In this instance the intervention was provided through workshops and distance education, which are features of the Training Model; and peer support which has the characteristics of the Community of Practice Model. In similar vein, Ono and Ferreira (2010) tried out a PD model, rooted in the Japanese learning study project, which falls under the umbrella of the action research model with the difference that it was being experimented in a South African context. Another study, also categorised under the action research model, is by Aldridge, Fraser and Sebela (2004), whose ancestry is the Australian learning environments project (Fraser, 1998; Taylor, Fraser & Fisher, 1997). This study aimed to help teachers implement more constructivist practices in their classrooms.

Evaluation of the impact/effectiveness of PD

Without exception all the reviewed studies evaluated the impact of PD, and hence its effectiveness, by focusing on the teacher. The most common approaches to evaluation of effectiveness identified include: using teacher questionnaires

– including validated instruments to assess shifts in PCK or TSPCK; learner questionnaires; post-event evaluation forms or ‘happy sheets’, teacher self-report measures; pre- and post-tests – including assignments and examinations; observing teachers’ lessons schedules; interviewing teachers; and analysing teachers’ reflective journals. For all the reviewed studies, all or some of these data sources were used to evaluate the effectiveness/impact of the PD specifically focusing on determining teacher changes or shifts in: subject matter and pedagogical knowledge, classroom practices, teaching skills, beliefs and attitudes. This is said, albeit that the study by Aldridge, Fraser, and Sebela (2004), administered a modified version of the Constructivist Learning Environment Survey (CLES) (Taylor, Fraser, & Fisher, 1997) to assess students’ perceptions of whether there was a change in the classroom teaching as a result of the teacher going through an action research PD programme. The CLES is based on the assumption that students’ perceptions of what happens in the classroom are a valid and reliable indicator of the teaching process. Taylor, Fraser, and Fisher (1997) suggest that teacher-researchers can validly employ it to monitor the development of constructivist approaches to teaching in science classrooms. This instrument has been used in many studies around the world (e.g. Ozkal, Tekkaya & Cakiroglu et al., 2009; Ahmad, Ching, & Yahaya et al., 2015). However, given the spirit of the current review, it is argued that this kind of evaluation still focuses on the teacher, as the CLES is in essence an evaluation of the teacher by students. It fails to indicate whether there are shifts in students’ performance and achievements as a result of the teacher’s participation in PD.

Outcomes of the PD

Overall, thirteen (65 %) of the twenty reviewed studies show that there was a shift or a change in science teachers’ content and pedagogical knowledge, teaching skills, classroom practices, beliefs and attitudes as a result of their involvement in PD. Three studies (15%) report that the PD was not successful in improving or changing teachers’ content and pedagogical knowledge, teaching skills, classroom practices, beliefs and attitudes. The results of the other four studies (20%) can be described as inconclusive because, either the data was insufficient to provide a concrete support for the efficacy of the PD model or the findings gave mixed signals.

Discussion

The aim of this systematic review was to determine which professional development models are effective in developing science teachers and how the effectiveness of PD has been evaluated focusing on research in basic education in post-apartheid South Africa.

The findings suggest that in post-apartheid South Africa, a wide range of teacher PD models are used by researchers and practitioners. Furthermore, based

on the reviewed studies, the results show that, overall, PD can in general have a positive impact on the teachers who participate in PD. The majority of the studies (65 %) point towards PD having improved or shifted the participating science teachers' content and pedagogical knowledge, teaching skills, classroom practices, beliefs and attitudes. These findings also show that without exception, researchers have evaluated the effectiveness of PD models focusing on determining changes and shifts happening to the teacher.

An interesting observation is that all the PD models tried out in South Africa have features and characteristics evident of a European/Western progeny (Johnson, Hodges & Monk, 2000). This remains so, irrespective of the fact some of the studies in the current review made attempts to modify the models to suit the South African context (e.g. Kriek & Grayson, 2009; Mokhele, 2013; Jita & Mokhele, 2014; Ono & Ferreira, 2010). In spite of these efforts the models largely remained the same Western models as described by Kennedy (2005). Johnson, Hodges and Monk (2000) have warned that Northern/Western ideas and paradigms of PD are unsuitable for modelling practices and challenges facing post-colonial countries. The centrality of Western hegemony in PD efforts is an affront to the processes of decolonisation and transformation of South Africa's science education. Chinn (2007) laments the damaging effects of Western hegemonic influence on teacher PD and suggests the use of critical indigenous knowledge based approaches. He argues that PD, which employs decolonising methodologies articulated through indigenous knowledge systems (IKS), has the potential to nurture teachers' awareness of linkages among their personal experiences, cultural practices, beliefs and values, and teaching and learning.

Having made these general observations, it is appropriate to address the review's research questions.

The effectiveness of teacher professional development models

Based on the reviewed studies, it appears that, in South Africa, PD has in general positively impacted on the teachers. The validity of this statement, however, should be taken with a measure. This is so because when the findings of this review are closely scrutinised and unpacked, this validity diminishes. According to these findings, the most popular and effective models are the cascade and training models with a combined total of seven studies showing that PD has a positive impact on teachers' knowledge, practices, skills etc. Other models which showed successes in at least one study are: action research, community of practice, coaching/mentoring, deficit, and transformative. None of the reviewed studies could confidently be categorised into two of Kennedy's (2005) models. These are the award-bearing model, and the standard-based model.

In answering the first of this review's research questions, it can be suggested that, generally, all the PD models used in the reviewed studies show success in

effective PD of science teachers in South Africa. This is so because in the majority of cases, the results of the PD process were positive. Such a broad generalisation, however, is difficult to sustain for two reasons. First, the number of reviewed studies (20) is too small to confidently support such a sweeping statement or claim. The paucity of research on this topic suggests that more studies need to be done to get a clearer picture. The fact that 35% of the studies were either negative or inconclusive decreases the assurance with which such a generalisation can be made. The second reason has to do with how the effectiveness of PD was evaluated, which leads to the second research question.

Evaluation of the effectiveness of science teacher professional development

As shown, the data analysis reveals that all the reviewed studies evaluated the effectiveness of PD, based on attributes which have to do with the teacher. Those studies which claim effectiveness of the PD process do so on the basis of changes or shifts in teachers' subject matter and pedagogical knowledge, classroom practices, teaching skills, beliefs and attitudes. There is an underlying assumption, that these observed changes or shifts are indicators not only of the impact of PD on teachers but also the effectiveness of PD. In turn, effective PD is presumed to translate into effective teaching.

It has been argued that determining improvements in student performance and achievement should be at the centre of the evaluation of the effectiveness of teacher PD (Earley & Porritt, 2014; Pedder, Opfer, & McCormick et al., 2010). It was also suggested that the achievement of effective evaluation of PD involves a balanced assessment of changes or shifts in: student learning outcomes, teacher knowledge, practices and efficacy, and a plethora of factors in the teaching and learning environment. The greatest weight of this equilibrium, however, should be given to determining improvements in student performance and achievement. Given that all the studies in this review focused evaluation of effectiveness of PD by determining what happens to the teacher, it is argued that no definitive conclusion can be arrived at regarding the effectiveness of the employed PD models. The approaches to evaluating effectiveness of PD used by the studies covered by the current review can be described as simplistic, impressionistic and untrustworthy as they are based on simple measures (Earley & Porritt, 2014). In other words, it is difficult to arrive at a conclusion regarding the efficacy of a PD model without factoring in the impact or effect that PD has had on improving the performance and achievement of students. The implications are that South African researchers and education practitioners need to seriously consider making assessment of student gains a part of evaluation of the effectiveness of PD. This is in line with the current thinking on PD evaluation (Pedder, Opfer, & McCormick et al., 2010).

Conclusions and recommendations

This systematic review has shown that in South Africa, several teacher professional development models have been tried on in-service and practising teachers. These models are: cascading, training, action research, community of practice, coaching/mentoring, deficit, and transformative. The results of the analysis reveal that in the majority of cases the models have been successful in improving the participating teachers' content and pedagogical knowledge, teaching practices, skills, beliefs and attitudes. The efficacy of these models should, however, be considered with caution because of the methods the researchers used to evaluate the effectiveness of PD. It is recommended that future evaluations of science teacher PD efforts should take into account the effect or impact of the PD on students' learning outcomes, performance and achievement. In order to achieve this, the design of PD and its evaluation should take the form of longitudinal studies, where the impact of the teachers' PD is monitored over time.

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