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# CONTEXTUALISING SCIENCE AND MATHEMATICS TEACHER PROFESSIONAL DEVELOPMENT IN RURAL AREAS

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## ABSTRACT

*Science and mathematics teacher professional development in South Africa does not adequately address teachers' pedagogical content knowledge or ability to integrate indigenous knowledge into the curriculum. This situation is partly due to traditional teacher professional development programmes that utilise top-down and expert-driven approaches without consulting teachers. This "one-size-fits-all" model is rarely relevant to teachers' classroom realities, especially in rural areas. The research question that guided this research was: How could the professional development intervention be contextualised to better meet the educational needs of a rural environment? In this paper, we explore the design principles for teacher professional development interventions that could address the needs of teachers and the context, acknowledging that teachers in rural areas face different challenges compared to teachers in urban areas. We use the Hantam region of the Northern Cape Province as a case study to explore the affordances of partnerships with local indigenous knowledge holders and cultural institutions (museums) in the professional development of teachers. Data were generated from semi-structured interviews with Hantam school and community participants using a qualitative approach. Two major themes that emerged from this qualitative research was that (a) the involvement of indigenous knowledge holders and museums as "third partners" in the value chain between universities and schools, could greatly assist to better contextualise the "western" science curriculum, and (b) the incorporation of indigenous knowledge in the STEM curriculum could assist in building the self-esteem of learners. We argue that contextualising science and mathematics teacher professional development for the rural environment has affordances for improving not only teacher competencies, but also learners' views on the relevance of science and mathematics in everyday life.*

**Keywords:** *Teacher professional development; contextualised curriculum; indigenous knowledge; rural areas; science and citizenship education.*

## 1. INTRODUCTION

In South Africa, education is essential for redressing past injustices and transforming society into a democratic



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nation-state. The Department of Education asserts that education is pivotal to economic prosperity and plays a key role in enabling citizens to improve the quality of their lives in contributing to a peaceful, productive and democratic nation (Department of Education, 2005). Positioned at the front lines of educational reform were science, technology, engineering and mathematics curriculum reform, of which professional development was a critical component (Villegas-Reimers, 2003). In order to be a global player in the world economy, South Africa needs innovative and creative scientists, but this means that science education in the country has to be greatly improved (Centre for Development and Enterprise, 2011). Conventional teacher professional development in the form of workshops, conferences, courses and seminars were initiated to improve identified skill deficits in content, curriculum and pedagogy (Rogan, 2004; Taylor, 2008; Kriek & Grayson, 2009). However, after two decades, teacher competency has not improved as envisaged (Tsoetsi & Mahlomaholo, 2015; De Beer, 2016). Researchers note that many professional development programmes are imported products, implemented uniformly from a top-down perspective and based on expert knowledge that is irrelevant to the classroom realities of teachers, especially in rural areas (Ball & Cohen, 1999; Bantwini, 2009; Ono & Ferreira, 2010; De Beer, 2016). In this paper we reflect on design principles for teacher professional development interventions that could better address the needs of teachers and the rural sector. We aim to address the gap between teacher professional development and their educational needs by investigating how teachers could be assisted to infuse indigenous knowledge into the science and mathematics curricula. This research contributes to the national “decolonising of the curriculum” debate by contextualising teacher professional development for a rural environment. The research question guiding this research was: *How could the professional development intervention be contextualised to better meet the educational needs of a rural environment?*

Many rural schools are located on former homelands, previously disadvantaged areas with a multitude of challenges to the achievement of quality education (McKinney, 2005; Stack *et al.*, 2011). Rural areas represent the poorest and least resourced areas of the country. However, science in these contexts is embedded in local indigenous knowledges of the environment through generations of observation and experiences (Aikenhead, 1996). De Beer and Mentz (2017) have shown that the holders of indigenous knowledge are often, per definition, self-directed learners who solved problems in their environment through processes very similar to the syntactical tools utilised by scientists. Through oral transmission, indigenous ways of knowing and practising science – as well as mathematics and technology – are vibrant in rural environments (Khupe, 2014). Researchers have documented the influence of cultural background on science education (Cameron, 2010; Manzini, 2006) as well as the connection between science and citizenship (Irwin & Wynne, 1996; Jasanoff, 2004). This paper explores teacher professional development from a community-based approach, recognising that schools are integrated into the fabric of rural communities. We explore the affordances of partnerships with indigenous knowledge holders and cultural institutions (museums) in the professional development of teachers. Similar to Jautse, Thambe and De Beer (2016), we allude to the fact that a “third partner” is needed in the value chain between schools and university teacher training to effectively prepare science teachers for a complex 21<sup>st</sup> century.

## 2. THEORETICAL FRAMEWORK

This paper views teacher professional development through a socio-cultural lens that engages knowledge and cultural assets of the local community. We integrate learning

theories – namely, social constructivism (Vygotsky, 1978) and embodied, situated and distributed cognition (Hardy-Vallee & Payette, 2008) – as a foundation from which to develop teachers professionally and promote life-long learning. We argue for a situational approach to professional development that considers teacher structures and supports that assist with knowledge transfer in classrooms (Darling-Hammond & McLaughlin, 1995; Rout & Behera, 2014).

## 2.1 Social constructivism; and embodied, situated and distributed cognition

We argue from the perspective of embodied, situated and distributed cognition (ESDC) that grants the body a central role in cognition (Wilson, 2002; Hardy-Vallee & Payette, 2008). Cognition is physiologically embodied, socio-culturally situated and distributed among the community. ESDC emphasises the connection between brain/mind and ongoing interaction with the physical and social environment (Reichelt & Rossmannith, 2008). This cognitive system guides action (Wilson, 2002). An important implication of ESDC is the role that different modalities such as bodily movements and cultural artefacts play in the understanding of science and mathematical concepts.

We situate ESDC within a social constructivist framework that engages teachers' prior knowledge in constructing new knowledge. Social constructivism focuses on the construction of knowledge as opposed to knowledge transfer typical of traditional teacher development programmes (Rout & Behera, 2014:11). Constructivism mirrors how learning takes place in the classroom environment. Koohang *et al.* (2009) assert that learning is enhanced when the teacher and learner roles are subsumed in the learning process. Social constructivism allows fluidity between these roles in the learning environment.

For Vygotsky (1978), social constructivism is at its best when teachers reach the “zone of proximal development” (ZPD) where the knowledge of the entire group is collectively increased. This learning process requires a range of learning tasks beyond the knowledge level of any individual group member. Mastery of the task requires that all learners are engaged in the process.

This framework provides a sound basis for context-specific professional development that is responsive to culture and relevant to teacher needs. We employ a contextualised approach to professional development that engages knowledge and the cultural assets of the local community, acknowledging that schools in rural areas are not entities separated from the cultural community.

## 2.2 Nature of indigenous knowledge and nature of science, and the conundrum facing us in science education

Several researchers have shown that many South African teachers do not hold nuanced understandings of the nature of science (Cronje, 2015; Pretorius, 2015). Abd-El-Khalick, Bell and Lederman (1998), who developed an instrument to capture teachers' views of the nature of science, make it clear that a relationship exists between teachers' views of concepts, and how they teach. The argument is that, if teachers have good understandings of the empirical and inferential nature of science, it might be reflected in how they create learning opportunities (e.g., favouring inquiry learning over transmission-mode approaches). Ramnarain and Schuster (2014) show that there are many systemic issues that influence such transfer in the

classroom. The latter authors have shown that teachers (especially in rural schools) often “teach-to-the-test”, despite their own pedagogical orientations, due to pressure from, among others, parents and principals to achieve good examination results.

Cronje (2015) developed an instrument to capture views on indigenous knowledge, based on the instrument developed by Abd-El-Khalick for views on the nature of science. She has shown that indigenous knowledge shares several tenets with the natural sciences, e.g., both are empirical, tentative, inferential and creative. There are, however, also differences, e.g., indigenous knowledge has a metaphysical character, unlike science. It is these metaphysical and holistic doctrines that create a conundrum regarding the inclusion of indigenous knowledge into the science and mathematics classroom. Taylor and Cameron (2016) show that there are three epistemological perspectives on such border-crossing: (a) indigenous knowledge is part of science; (b) indigenous knowledge and science are different domains of knowledge, and border-crossing is not advisable; and (c) indigenous knowledge and science should be seen as intersecting domains, and the focus in the classroom should be on the “shared space” between the domains. This complexity and uncertainty raise another concern: are teacher educators equipped to provide teachers (in-service training) and student-teachers (pre-service teacher education) with a good understanding of this complexity? This is the gap that this paper explores. How could a collaboration with the holders of indigenous knowledge and museums, as a “third partner”, address this concern?

### 3. METHODOLOGY

#### 3.1 The short-learning programme

The Namaqua district covers an area of 126,836 square kilometres and includes six municipalities, namely the Richtersveld, Nama Khoi, Kamiesberg, Hantam, Karoo Hoogland and Khai-Ma. This research focused on the Hantam region that is bounded geographically by the Hantam Mountains, with the town Calvinia forming the hub of the region. It contains flora, fauna, indigenous knowledge and culture specific to this geographical region. Of specific interest, is that a sizable proportion of the people in this area are of Khoi-San (Nama, Griqua and *!Xam*) ancestry (De Beer, 2012). Adhering to the design-based research principles described by Anderson and Shattuck (2012), research requires long-term engagement and intensive collaboration in the research context to improve short-learning programmes (SLPs). The first cycle of the design-based research started with an SLP in the Hantam district in 2017.

The first SLP set out to build teacher capacity to facilitate epistemological border-crossing between indigenous knowledge and science curriculum topics. In the SLP, the focus was on problem-based learning, e.g., teachers engaged in an adapted Kirby-Bauer technique (Mitchell & Cater, 2000) to test anti-microbial activity of medicinal plants as well as cooperative learning, e.g., methods such as De Bono’s thinking hats.

Cycle 2 of the design-based research began seven months later with a community-based qualitative inquiry exploring indigenous knowledge resources and the educational needs of the sector. The community inquiry and intervention follow-up ran concurrently.

#### 3.2 Research design

This research was designed to investigate a professional development SLP for science, technology and mathematics (STEM) teachers in the Hantam area in the Northern Cape. The Hantam professional development course is an example of professional development

that considers the social, cultural and historical context of rural education. According to Stake (2005), a case study is distinguishable by its unit of study in a bounded system. Yin (2014) adds that a case study is an empirical inquiry investigating a phenomenon in its real-life context. This research proceeded as a qualitative case study because the boundaries between phenomenon and context were blurred (Yin, 2014). The aim in Cycle 2 was to see how inputs from indigenous knowledge holders could further enhance the impact of the SLP.

### 3.3 Data sampling

#### 3.3.1 Population

The target population included community members and teachers in the Hantam district. A total of seventy-seven (77) teachers and eight (8) community members voluntarily participated in this research study. Of the teachers who participated in the SLP, thirty-seven (37) science teachers and forty (40) mathematics teachers volunteered. Community member participants included indigenous knowledge holders, the museum curator and officials from the Department of Basic Education. Most notable of the community member participants, were the local holders of indigenous knowledge.

#### 3.3.2 Sampling techniques

A snowball sampling method was used to invite Hantam residents to participate in the second cycle of research. Semi-structured interview conversations were conducted with eight (8) community members (notably the holders of indigenous knowledge), museum staff (the Calvinia Museum) and officials from the Department of Education. During Cycle 1, STEM teachers in the Namaqua District were invited to participate in an SLP held in the town of Calvinia. The criteria for inclusion were that participants were STEM teachers who had the desire and ability to travel to Calvinia to participate in a professional development course. These criteria were met by all participating teachers in the SLP. At the conclusion of the course, attending teachers were asked to voluntarily participate in the study. Those who volunteered were a random sample of the SLP participants. Purposeful random sampling lends credibility to the sample as Palinkas *et al.* (2015: 534) suggests.

Purposive sampling was used to select community member participants. Patton (2002) recommends purposive sampling in qualitative research to render information-rich cases. The purposive strategy was employed with snowball sampling to recruit a homogeneous population of community members. Snowball sampling is based on the connectivity of the community, as volunteers suggest other possible volunteers who have similar characteristics (Huberman, 1994:90). In this regard, we were interested in indigenous knowledge holders in the Hantam region. We relied on familial and network connections of the community “gatekeeper” as a strategy to collect a homogeneous sample of knowledge holders.

This combination of strategies was deemed most effective for our research design and the best use of our limited resources. The sample size in this study was chosen to ensure data saturation, in order to distil design principles for contextualised teacher professional development (Yin, 2003). While this case is not intended to generalise to all contexts, we do expect the findings to generalise to the “underlying” context of the study (Onwuegbuzie, 2003:400), namely teacher professional development in the rural context within South Africa.

### 3.4 Data collection

This research proceeded in two phases. The first phase was the SLP conducted in the Hantam region. The second phase involved community-based inquiry. This phase occurred eight (8) months later in the Hantam community. Each phase is explained in detail below.

#### Phase 1

A total of seventy-seven (77) teachers attended the intervention – thirty-seven (37) science teachers and forty (40) mathematics teachers. Teachers voluntarily completed one-on-one interviews during the two-day intervention. After the intervention, they were granted six months in which to complete portfolios documenting the application of professional development skills and indigenous knowledge integration into their classroom instruction. Data obtained from teacher interviews and professional development portfolios assisted facilitators to distil new design principles to better serve the educational needs of teachers in the rural Hantam context.

#### Phase 2

A total of eight (8) community members consented to voluntarily participate in the research. All eight participants were residents of the Hantam community. One participant was a museum curator, three were indigenous knowledge holders (one employed by the museum) and four were community residents. All participants volunteered to participate in an audio-recorded biographical interview guided by a semi-structured questionnaire. Two participants completed a video narrative explaining indigenous knowledge and Hantam culture.

The semi-structured biographical interview protocol comprised seven (7) questions. The semi-structure was selected to allow participants to narratively reflect on their residence in the Hantam community and the culture of the place. This structure also allowed participants to engage in storytelling, which is a mode of cultural transmission in indigenous knowledge systems. The first three questions were biographical in nature, specifically asking participants about the length of their residence in the Hantam area. One question asked whether the participant's family had generational residence in the area. The remaining questions were topical to explore aspects of daily life and cultural values that community members hold dear. Participants could choose to skip questions they experienced as uncomfortable. The biographical interview was audio recorded.

The video narrative was purposed to capture visual images and representations of science in their daily lives. Participants were issued cameras and asked to take pictures of aspects of nature and the environment that represent science and citizenship. In a subsequent meeting, participants were asked to explain the significance of the images.

### 3.5 Data analysis

Data included researcher observations and field notes, oral interviews and video narratives. Interviews and narratives were transcribed and coded along with researcher notes. Descriptive codes were used according to Saldana's (2009) technique. Themes emerged from the process of coding and categorising the data. Codes were grouped into categories and themes emerged from comparison of categories with the research question. This paper reports preliminary findings of the ongoing design-based research.

### 3.6 Ethical considerations

Ethical clearance was obtained from the university (NWU-00271-16-A2 for Cycle 1; NWU-HS-2017-0135 for Cycle 2) and community gatekeepers. Two participants volunteered to record video narratives explaining indigenous knowledge and Hantam culture. Permission for teacher participation in the study was sought in writing from the Department of Basic Education in the Namakwa District. Permission for involvement of Khoi-San indigenous knowledge holders was obtained from community gatekeepers. We were also guided in this research by the San Code of Research Ethics (2017), the first indigenous code of researcher ethics in Africa. All volunteers were requested to complete an informed consent form that explained the research aims and objectives and volunteers' right to withdraw from the study at any time. The consent included an explanation of risks and benefits associated with participation in the study. Volunteers completed an interview. Privacy and confidentiality were observed by the use of pseudonyms and firewall data protection.

## 4. FINDINGS

Themes emerging from the data show that education in the Hantam rural environment is embedded in the social and cultural fabric of the area. Education is connected to indigenous knowledge, cultural artefacts and issues of social justice. Professional development initiatives would do well to consider the cultural context of rural schools to better meet the needs of teachers in these environments. This paper reports preliminary findings of ongoing research.

### 4.1 Theme 1: Social connectedness of education and contextualised STEM education

Participants indicated that education in the rural environment is not an isolated institution. Memci, the Calvinia Museum Curator, stated that she often collaborates with teachers and students to provide resources and needed support for teachers:

Every year, foundation phase learners come to the museum to do their history project. I take them on a tour of the museum and show them the resources we have here. I work with the teachers to organize the learners to come every year.

Memci nurtured the educational connection between community and schools by providing cultural and historical artefacts to assist learners in constructing history projects. In the Hantam rural context, sustainable professional development should utilise already existing community connections.

Education in the Hantam is everyone's business. Gammie, the local traffic policeman, utilises the school to connect students with cultural knowledge through the *rieldans*. The *rieldans* is a form of Khoi-San cultural knowledge that promotes cultural identity and community engagement (Van Wyk, 2013). Gammie boasts:

The *rieldans* is the property of the Khoisan people. It is their knowledge and identity. The *rieldans* is important because people of Khoisan roots are losing their identity from Western influence.

Gammie's dance troops are students in local schools that come from farms. His work maintains the connection between farms and schools in the Hantam. Gammie explained how he uses the *rieldans* to encourage educational achievement:

I tell them they can do anything. They can use what they learn on the farm in school. The *riedans* is knowledge of the farm and they can be proud of what they know from the farm.

The need for contextualised teacher professional development prompted the teacher educators in this project to focus on the affordances of traditional music for learning in the mathematics classroom. Owing to generous funding obtained from the Fuchs Foundation, teachers and school learners were provided with “boom whackers”, plastic pipes of various lengths, that can be used as music instruments. These boom whackers were accompanied by sheet music, in which learners are taught about fractions (Figure 1). Boom whackers are coloured plastic tubes that work in the same way as xylophones. Music symbols were transposed to mathematical symbols (fractions, e.g.,  $\frac{1}{4}$ ,  $\frac{1}{2}$ , etc.) with the size of the fraction indicating the time duration of the “hit” (Van der Walt & Potgieter, 2019).



**Figure 1:** Teaching fractions in the mathematics classroom as inspired by indigenous music

Additionally, Khoi-San indigenous knowledge and culture is embedded in the Hantam local culture. Education is not separate from social and economic issues affecting Hantam residents. Christien, an indigenous knowledge holder staying on a farm in the Agter-Hantam, stated: “I wish I could have been a teacher so I can teach the children about my plants and medicines. It is important for them to know what plants can do.”

Christien’s desire to pass on or transmit knowledge to future generations is a tenet of indigenous knowledge. She also recognised the importance of Khoi-San indigenous knowledge to science education in Hantam classrooms as she referenced medicinal properties of plants. In the Hantam many people rely on plants for medicinal purposes (De Beer, 2012). Christien also recognised the connection between education and economic issues in the farm community: “My son has the knowledge. He wanted to be a teacher but we work on the farm. We don’t have money to send him to varsity.”

Christien's dream of transmitting indigenous knowledge to teachers and students can be realised through the local museum. The museum curator agreed to house the memorial garden of Khoi-San medicinal plants, indigenous to the Hantam. The museum will also house a permanent exhibit of Khoi-San indigenous knowledge and influence in the Hantam area. These exhibits are an outgrowth of the cultural research we embarked on to contextualise the professional learning intervention.

In the second half of 2017, we embarked on a teacher professional development programme for Life Sciences teachers in which insights about the importance of ethnobotany in this region resulted in tailor-made activities. De Beer and Van Wyk (2011) conceptualised the so-called Matrix Method for engaging in ethnobotanical surveys in the classroom. Teachers' learning was scaffolded in this regard and they were introduced to ethnobotanical activities that learners can engage with in the Life Sciences classroom, such as an adapted Kirby-Bauer technique (Mitchell & Cater, 2000) to test whether medicinal plants that are culturally used, have any antimicrobial activity, as well as doing ethnobotanical surveys in the community. One of the teachers, Marlize, indicated that this resulted in much enthusiasm among her learners and the attainment of affective outcomes. One of the teachers started a project where her learners engaged in making herbarium voucher specimens for a class herbarium (Figure 2).



**Figure 2:** Resources that were provided to schools (herbarium presses and autoclaves) on the left-hand side, and a learner's project in ethnobotany on the right-hand side

The involvement of a holder of indigenous knowledge such as Christien, through her involvement in the museum, is able to provide a teaching and learning resource that could lead to more contextualised science education.

## 4.2 Theme 2: The affordances of indigenous knowledge in STEM education for building self esteem

Community participants indicated that they were alienated from educational institutions in the past. However, educational opportunities are available for adults since 1994. For Gertjie, education was connected to social justice. He was unfairly denied education in his youth because he lived on a farm: "I had to work on the farm. When I could go to school, the farmer said I had hair on my face, I need to work on the farm."

When educational opportunities were made available, Gertjie was denied the privilege of going to school because "he had hair on his face" (referring to the fact that, as an adolescent, he had a beard); otherwise stated he was too old and more useful as a farm worker than as a learner in school. In adulthood, Gertjie realised education as his human right through literacy programmes. He can now learn to read and write. In his words: "No one has to read for me, I can read myself."

Education is embedded in community life, but local indigenous knowledge is not common in school classrooms. Carin, a Foundation Phase administrator, asserted:

Khoi-San indigenous knowledge and stories should be in the curriculum to build confidence in the learners. Most of them (learners in her school) are Khoi-San. They have the knowledge at home and in their communities, but it has to stay at home when they come to school.

Integrating communities in schools holds innumerable benefits for building children's self-esteem. Older participants stated that indigenous knowledge was confined to the realm of the home. It was not valid in schools. Carin explained that Khoi-San indigenous knowledge is the way that she knows in the veld. She grew up hearing Khoi-San stories about the veld. She learned about the environment and atmosphere from those stories. She regards indigenous knowledge as essential for building the self-esteem of children. However, this knowledge is not included in the curriculum.

The intimate connection between education, community and indigenous knowledge in the Hantam is best illustrated by a vignette from Marlize's ethnobotanical survey. One of her Grade 10 learners, Henrico, was so inspired by this assignment that he visited the Calvinia library and he asked the librarian for books on the flora of the Hantam. He was given a dissertation on the ethnobotany of the Hantam (De Beer, 2012), and while working through the text, he stumbled upon a photograph of his uncle, Martiens. The latter was consulted during this ethnobotanical survey in 2012. Henrico was so inspired by this "knowledge in the blood", that he decided that he would like to pursue a career in botany after passing Grade 12. The acknowledgement of his own cultural knowledge did much to build his self-esteem and a sense of pride in his rich Khoi-San heritage.

## 5. DISCUSSION AND CONCLUSION

Nelson Mandela (2005:vi) stated "the most profound challenges to South Africa's development and democracy can be found in its rural hinterlands". Rural environments are typically areas of high concentrations of poverty, unemployment and low educational attainment (Myende, 2014).

The historically present depravation of South Africa's rural areas makes quality education not only an imperative but also an issue of social justice and citizenship (Odora-Hoppers, 2004). Teacher professional development in the rural Hantam environment was contextualised by building on existing community partnerships and integrating Khoi-San indigenous knowledge into STEM classrooms. This community-based approach informed the design of teacher professional development aligned with the educational needs of the community. Embodied, distributed and situated cognition provided a foundation to explore the interaction between physical and social environment that is active in indigenous knowledge contexts. The use of embodied ways of knowing decolonises ways of knowing and practising science and mathematics in STEM classrooms. The embodied perspective also provided a lens through which to explore the affordances of cultural assets in contextualising teacher professional development. The contextualised teacher professional development approach presented in this paper strengthened partnerships between the community and schools aimed at improving teacher competencies and making science and mathematics instruction relevant to the learners. Contextualised teacher professional development has the potential to

harness knowledge assets and cultural resources present in rural communities, making social transformation a possibility.

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## REFERENCES

- Abd-El-Khalick, F., Bell, R.L. & Lederman, N.G. 1998. The nature of science and instructional practice: Making the unnatural natural. *Science Education*, 82: 417–437. [https://doi.org/10.1002/\(SICI\)1098-237X\(199807\)82:4<417::AID-SCE1>3.0.CO;2-E](https://doi.org/10.1002/(SICI)1098-237X(199807)82:4<417::AID-SCE1>3.0.CO;2-E).
- Aikenhead, G.S. 1996. Science education: Border crossing into the subculture of science. *Studies in Science Education*, 27: 1–52. <https://doi.org/10.1080/03057269608560077>.
- Anderson, T. & Shattuck, J. 2012. Design-based research: A decade of progress in education research? *Educational Researcher*, 41(1) 16–25. <https://doi.org/10.3102/0013189X11428813>.
- Ball, D. & Cohen, D. 1999. Developing practice, developing practitioners: Towards practice-based theory of professional education. In L. Darling-Hammond & G. Sykes (Eds.). *Teaching as the Learning Profession*. San Francisco, CA: Jossey Bass.
- Bantwini, B. 2009. District professional development models as a way to introduce primary-school teachers to natural science curriculum reforms in one district in South Africa. *Journal of Education for Teaching International Research and Pedagogy*, 35(2): 169–182. <https://doi.org/10.1080/02607470902771094>.
- Cameron, A. 2010. Reaching for the stars: Improving epistemological access through understanding student values. *XIV IOSTE Symposium: Socio-cultural and human values in science and technology education* (pp. 220–228). Bled, Slovenia.
- Centre for Development and Enterprise. 2011. Value in the classroom. A. Bernstein (Ed). *CDE In Depth Nr 11*.
- Creswell, J.W. 2013. *Qualitative inquiry & research design*, 3rd edition. Thousand Oaks, CA: Sage.
- Cronje, A. 2015. Epistemological border-crossing between western science and indigenous knowledge and its implications for teacher professional development. Unpublished PhD thesis. Johannesburg: University of Johannesburg.
- De Beer, J. 2012. An ethnobotanical survey of the Agter-Hantam, Northern Cape Province. Unpublished M.Sc dissertation. Johannesburg: University of Johannesburg.
- De Beer, J. 2016. Re-imagining science education in South Africa: The affordances of indigenous knowledge for self-directed learning in the school curriculum. *Journal for New Generation Sciences*, 14(3): 34–53.
- De Beer, J. & Mentz, E. 2017. 'n Kultuurhistoriese aktiwiteitsteoretiese blik op die houers van inheemse kennis as selfgerigte leerders: Lesse vir onderwys in Suid-Afrikaanse skole. *Suid-Afrikaanse Tydskrif vir Natuurwetenskap en Tegnologie*, 36(1): 1–11. <https://doi.org/10.4102/satnt.v36i1.1474>.

- De Beer, J. & Van Wyk, B-E. 2011. Doing an ethnobotanical survey in the Life Sciences classroom. *The American Biology Teacher*, 73(2): 90–97. <https://doi.org/10.1525/abt.2011.73.2.7>.
- Department of Education. 2005. *Education for all – 2005 Country status report: South Africa*. Pretoria: Department of Education.
- Hardy-Vallee, B. & Payette, N. 2008. *Beyond the brain: Embodied, situated and distributed cognition*. Newcastle: Cambridge Scholars Publishing.
- Irwin, A. & Wynne, B. 1996. *Misunderstanding science?: The public reconstruction of science and technology*. Cambridge, UK: Cambridge University Press. <https://doi.org/10.1017/CBO9780511563737>.
- Jautse, P.P., Thambe, N. & De Beer, J. 2016. *A day at the museum: A case study of how museums could partner with universities in teacher education. Proceedings of the ISTE Conference on Mathematics, Science and Technology Education, 24–28 October 2016*, pp. 438–445.
- Jasanoff, S. 2004. *States of knowledge: The co-production of science and the social order*. London, UK: Routledge. <https://doi.org/10.4324/9780203413845>.
- Khupe, C. 2014. *Indigenous knowledge and school science: Possibilities for integration*. Unpublished PhD thesis. Johannesburg: University of Witwatersrand.
- Koohang, A., Riley, L., Smith, T. & Schreurs, J. 2009. E-Learning and constructivism: From theory to application. *Interdisciplinary Journal of E-Learning and Learning Objects*, 5(1): 91–109. <https://doi.org/10.28945/3321>.
- Kriek, J. & Grayson, D. 2009. A holistic professional development model for South African physical science teachers. *South African Journal of Education*, 29: 185–203. <https://doi.org/10.15700/saje.v29n2a123>.
- Mandela, N. 2005. *A note from Madiba. Emerging voices: A report on education in South African rural communities* (pp. vi). Nelson Mandela Foundation: HSRC.
- Manzini, S. 2006. *Report on the implementation of an African socio-cultural approach to science teaching: Application of the collateral learning theory. Proceedings of 12th International Organisation for Science and Technology Education, Symposium, Penang, Malaysia*, pp. 636–643.
- Mckinney, C. 2005. *Textbooks for diverse learners: A critical analysis of learning materials in South African Schools*. Cape Town: Human Sciences Research Council.
- Mitchell, J.K. & Cater, W.E. 2000. Modeling antimicrobial activity of Clorox using an agar-diffusion test. *Bioscience*, 26(3): 9–13.
- Myende, P.E. 2014. *Improving academic performance in rural schools through the use of an asset-based approach as a management strategy*. Unpublished PhD thesis. Bloemfontein: University of the Free State.
- Odora-Hoppers C.A. 2004. The cause, the object, the citizen: Rural school learners in the void of intersecting policies and traditions of thought. *Quarterly of Education and Training in South Africa*, 11(3): 17–22.

- Ono, Y. & Ferreira, J. 2010. A case study of continuing teacher professional development through lesson study in South Africa. *South African Journal of Education*, 30(1): 59–74. <https://doi.org/10.15700/saje.v30n1a320>.
- Palinkas, L.A., Horwitz, S., Green, C., Wisdom, J., Duan, N. & Hoagwood, K. 2015. Purposeful sampling for qualitative data collection and analysis in mixed method implementation research. *Administrative Policy for Mental Health*, 42: 533–544. <https://doi.org/10.1007/s10488-013-0528-y>.
- Patton, M.Q. 2002. Two decades of developments in qualitative inquiry: A personal, experiential perspective. *Qualitative Social Work*, 1(3): 261–283. <https://doi.org/10.1177/1473325002001003636>.
- Pretorius, E.D. 2015. Learning communities for the professional development of science teachers. Unpublished PhD thesis. Johannesburg: University of Johannesburg.
- Ramnarain, U. & Schuster, D. 2014. The pedagogical orientations of South African physical sciences teachers towards inquiry or direct instructional approaches. *Research in Science Education*, 44: 627–650. <https://doi.org/10.1007/s11165-013-9395-5>.
- Reichert, A. & Rossmanith, N. 2008. Relating embodied and situated approaches to cognition. In B. Hardy-Vallee & N. Payette (Eds.). *Beyond the brain: Embodied, situated and distributed cognition*. United Kingdom: Cambridge Scholars Publishing.
- Rogan, J. 2004. Out of the frying pan...? Case studies of the implementation of curriculum 2005 in some science classrooms. *African Journal of Research in SMT Education*, 8: 165–179. <https://doi.org/10.1080/10288457.2004.10740570>.
- Saldana, J. 2009. *The coding manual for qualitative researchers*. London, UK: Sage Publications.
- San Code of Research Ethics. 2017. Available at <http://trust-project.eu/wp-content/uploads/2017/03/San-Code-of-RESEARCHEthics-Booklet-final.pdf> [Access 24 September 2018].
- Stack, S., Beswick, K., Brown, N., Bound, H., Kenny, J. & Abbott-Chapman, J. 2011. Putting partnership at the center of teachers' professional learning in rural and regional contexts: evidence from case study projects in Tasmania. *Australian Journal of Teacher Education*, 36(12): 1–20. <https://doi.org/10.14221/ajte.2011v36n12.7>.
- Stake, R.E. 2005. Qualitative case studies. In: N.K. Denzin & Y.S. Lincoln (Eds.). *The Sage handbook of qualitative research*, 3rd edition. Thousand Oaks, CA: Sage.
- Taylor, N. 2008. *What's wrong with South African schools? Proceedings of the Conference on What's Working in School Development*. Johannesburg: JET Education Services.
- Taylor, D. & Cameron, A. 2016. Valuing IKS in successive South African physical sciences curricula. *African Journal of Research in Mathematics, Science and Technology Education*, 20(1): 35–44. <https://doi.org/10.1080/10288457.2016.1147800>.
- Tsotetsi, C.T. & Mahlomaholo, M.G. 2015. Exploring strategies to strengthen continuing professional development of teachers in rural South Africa. *Journal of Higher Education in Africa*, 13(1&2): 45–74.
- Van der Walt, M., Potgieter, E. & Jagals, D. 2019. The affordances of indigenous knowledge in Mathematics education. In J. de Beer (Ed). *The decolonization of the curriculum project: The*

*affordances of indigenous knowledge for self-directed learning*. Stellenbosch: AOSIS. <https://doi.org/10.4102/aosis.2019.BK133.07>.

Van Wyk, M. 2013. [Re]vitalize Khoisan art and culture via a community outreach initiative. *Studies of Tribes and Tribals*, 11(2): 145–151. <https://doi.org/10.1080/0972639X.2013.11886676>.

Villegas-Reimers, E. 2003. *Teacher professional development: An international review of the literature*. Paris: UNESCO International Institute for Education Planning.

Vygotsky, L.S. 1978. *Mind in society*. London: Harvard University Press.

Wilson, M. 2002. Six views of embodied cognition. *Psychonomic Bulletin & Review*, 9(4): 625–636. <https://doi.org/10.3758/BF03196322>.

Yin, R.K. 2014. *Case study research: Design and methods*, 5th edition. Thousand Oaks, CA: Sage.