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Volume 2

The decolonisation of the curriculum project

The affordances of indigenous knowledge for self-directed learning

Edited by:

Josef de Beer

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EDITOR
Josef de Beer

AOSIS

Peer review declaration

The publisher (AOSIS) endorses the South African 'National Scholarly Book Publishers Forum Best Practice for Peer Review of Scholarly Books'. The manuscript was subjected to a rigorous two-step peer review prior to publication, with the identities of the reviewers not revealed to the author(s). The reviewers were independent of the publisher and/or authors in question. The reviewers commented positively on the scholarly merits of the manuscript and recommended that the manuscript should be published. Where the reviewers recommended revision and/or improvements to the manuscript, the authors responded adequately to such recommendations.

Research Justification

This book is the result of a longitudinal research project (2016—2018) funded by the National Research Foundation and the Fuchs Foundation, and it disseminates original research. The project researched the affordances of indigenous knowledge in the school Science, Technology and Mathematics curricula. Short learning programmes (SLPs) were offered to Science, Technology, Engineering and Mathematics (STEM) teachers, during which they engaged in creative and inquiry-based teaching and learning strategies. Research shows that strategies such as problem-based and cooperative learning have the potential to enhance self-directed learning. This design-based research was conducted in several provinces in South Africa (North-West Province, the Northern Cape, Limpopo province, and Gauteng). Based on the data obtained after each intervention, design principles were formulated for redesigning of SLPs. The qualitative research focussed on teachers' lived experiences of the epistemological border-crossing between Natural Science and indigenous knowledge, their views on the nature of science and indigenous knowledge, and the reformed teaching and learning that took place after the intervention in teachers' classrooms. Most of the chapters in the book report empirical data, with the exception of three chapters (Ch. 2, Ch. 10 and Ch. 11), that can be categorised as systematic reviews. The book is devoted to scholarship in the field of STEM education and teacher professional development, with a specific focus on research into the enhancement of self-directed learning. The target audience are scholars working in the fields of indigenous knowledge systems, STEM education, teacher professional development and self-directed learning. This book makes a unique contribution in terms of, firstly, its extensive use of third-generation Cultural-Historical Activity Theory (CHAT) as a research lens and, secondly, in drawing on research from the fields of neuroscience, science education philosophy, self-directed learning and indigenous knowledge systems, in arguing for such border-crossing. Chapter 1 shows how this research contributes to the development of fourth-generation CHAT, which, owing to the complexity of the object (which Engeström refers to as 'runaway objects'), requires a focus on numerous activity systems. The book also explores the conundrum of research ethics during participatory action research with holders of indigenous knowledge.

In accordance with the requirements of the Department of Higher Education and Training, this book contains more than 50% original content, and no part of the work has been plagiarised. Ethical clearance for the project was provided by the North-West University's Faculty of Education Research Ethics Committee.

Josef de Beer, Research Unit Self-Directed Learning Faculty of Education, North-West University Potchefstroom, South Africa

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Abbreviations, Figures and Tables Appearing in the Text and Notes

List of Abbreviations

ABT	American Biology Teacher
CAPS	Curriculum and Assessment Policy Statement
CAR	Classroom Action Research
CDE	Centre for Development and Enterprise
CHAT	Cultural-Historical Activity Theory
CL	Cooperative Learning
CoP	Community of Practice
CSIR	Council for Scientific and Industrialised Research
DBE	Department of Basic Education
DBR	Design-based Research
DEET	Diethyltoluamide
DoE	Department of Education
EASA	Education Association of South Africa
EKI	Ethnobotanical Knowledge Index
ESDC	Embodied, Situated and Distributed Cognition
FET	Further Education and Training
GIS	Geographical Information Systems
ICT	Information and Communication Technology
IK	Indigenous Knowledge
IKS	Indigenous Knowledge Systems
IP	Intellectual Property
IT	Indigenous Technology
LP	Learning Progression
MKT	Mathematical Knowledge for Teaching
NDP	National Development Plan
NOIK	Nature of Indigenous Knowledge
NOS	Nature of Science

NRF	National Research Foundation
NWU	North-West University
OER	Open Educational Resources
PBL	Problem-based Learning
PCK	Pedagogical Content Knowledge
PD	Professional Development
PDFDL	Professional Development Framework for Digital Learning
PI	Partially Informed
PoP	Pedagogy of Play
PRRE	Policy and Rules for Research Ethics
RIMP	Rationality Index for Magic Plants
RTOP	Reformed Teaching Observation Protocol
SCD	Systematic Country Diagnostic
SDL	Self-directed Learning
SKA	Square Kilometre Array
SLP	Short Learning Programme
SMK	Subject Matter Knowledge
STEAM	Science, Technology, Engineering, Arts and Mathematics
STEM	Science, Technology, Engineering and Mathematics
TIMSS	Trends in Mathematics and Science Study
UI	Uninformed View
VNOIK	Views-on-the-Nature-of-Indigenous-Knowledge
WIL	Work-integrated Learning
ZPD	Zone of Proximal Development
ZPTD	Zone of Proximal Teacher Development

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Notes on Contributors

Roxanne Bailey

School of Mathematics, Science and Technology Education, Faculty of Education, North-West University, Potchefstroom, South Africa; Research Unit Self-Directed Learning, Faculty of Education, North-West University, Potchefstroom, South Africa
Email: Roxanne.bailey@nwu.ac.za
ORCID: https://orcid.org/0000-0001-5326-274X

Dr Roxanne Bailey is a senior lecturer in the Computer Science Education subject group at the Faculty of Education, North-West University. She is also the leader of the subarea of the specialisation, 'Cooperative learning', within the Research Unit Self-directed Learning. Her main research focus is on the promotion of self-directed learning through the implementation of cooperative learning. She has received several research grants and is currently involved in three research projects set at investigating technology-supported cooperative learning. Roxanne was also selected as one of three research fellows to complete a 4-month fellowship under the guidance of the UNESCO Chair for Personalised and Adaptive Distance Education. She has published at the national and international levels, and she also acts as a supervisor for postgraduate students.

Susan Bester

Self-Directed Learning, School of Commerce and Social Sciences in Education, Faculty of Education, North-West University, Potchefstroom, South Africa; Research Unit Self-Directed Learning, Faculty of Education, North-West University, Potchefstroom, South Africa
Email: 10618635@nwu.ac.za
ORCID: https://orcid.org/0000-0002-9036-761X

Dr Susan Bester is a senior lecturer in the Faculty of Education, North-West University. She completed her BA, BA Honours, MA and PhD degrees from North-West University. Her research focus is on the use of engaging pedagogies in History.

Josef de Beer

Research Unit Self-Directed Learning, Faculty of Education, North-West University, Potchefstroom, South Africa
Email: josef.debeer@nwu.ac.za
ORCID: https://orcid.org/0000-0002-2411-6599

Prof. Josef de Beer is a research professor in the Faculty of Education, North-West University. He has been working in the field of teacher education for the past 28 years, and his research interests include the epistemological border-crossing between Western science and indigenous knowledge, and the affordances of indigenous knowledge in the science classroom. His research project, 'Teachers without Borders' is one of 12 national flagship programmes funded by the Fuchs Foundation. He is a National Research Foundation rated researcher (established researcher) and has published extensively in the fields of science education and teacher education. He is a co-editor of the acclaimed book, *Becoming a Teacher*, published by Pearson. He has received many accolades including a Higher Education Learning and Teaching Association of Southern Africa national award for teaching excellence in 2009, the Vice-Chancellor's Award for teaching excellence at the University of Johannesburg in 2008 and the American National Association of Biology Teachers Award for Research Excellence in 2012. In 2019, Prof. De Beer received the National Research Foundation's 'Excellence in Science Engagement' award. He was also awarded the Education Association of South Africa (EASA) 2020 Medal of Honour, for his contribution towards education.

Washington T. Dudu

School of Mathematics, Science and Technology Education, Faculty of Education, North-West University, Mafikeng, South Africa; Research Unit Self-Directed Learning, Faculty of Education, North-West University, Potchefstroom, South Africa
Email: Washington.Dudu@nwu.ac.za
ORCID: https://orcid.org/0000-0002-0194-0833

Prof. Washington T. Dudu is the Deputy Dean of Research & Innovation in the Faculty of Education, North-West University. He has been working in the field of teacher education for the past

14 years. As part of the community engagement enterprise, Washington has also been running the Experimento-Stiftung international project where he has trained a large number of practising teachers in providing didactic and methodological approaches to classroom experiments using an inquiry-based approach to science education. Washington's research interests are in scientific inquiry, nature of science, pedagogical content knowledge and the affordances of indigenous knowledge in the science classroom.

Aubrey Golightly

School of Mathematics, Science and Technology Education, Faculty of Education, North-West University, Potchefstroom, South Africa; Research Unit Self-Directed Learning, Faculty of Education, North-West University, Potchefstroom, South Africa
Email: Aubrey.golightly@nwu.ac.za
ORCID: https://orcid.org/0000-0001-5744-1438

Prof. Aubrey Golightly holds a doctoral degree and is an associate professor in Geography Education in the School of Mathematics, Science and Technology Education, Faculty of Education, North-West University, Potchefstroom Campus. He teaches various academic and subject methodology Geography modules. His research interests are active learning, problem-based learning, self-directed learning, self-directed professional development and experiential learning (Kolb's learning styles) in Geography Education. His current research project concerns the training of pre-service Geography teachers in the implementation of problem-based learning in secondary schools as well as Geography teachers' involvement in self-directed professional development activities. He is a member of the editorial board of the *International Research in Geographical and Environmental Education*.

Marietjie Havenga

School of Mathematics, Science and Technology Education, Faculty of Education, North-West University, Potchefstroom, South Africa; Research Unit Self-Directed Learning, Faculty of Education, North-West University, Potchefstroom, South Africa
Email: marietjie.havenga@nwu.ac.za
ORCID: https://orcid.org/0000-0003-1638-9834

Prof. Marietjie Havenga is an associate professor in the School of Mathematics, Science and Technology Education, Faculty of Education, North-West University. Her research interests include problem-based and project-organised learning to enhance self-directed learning, with specific reference to Computer Science Education and engineering education. She is a National Research Foundation (NRF) rated researcher and has received an NRF project grant. She has published in national and international journals and is involved in the supervision of postgraduate students.

Divan Jagals

School for Professional Studies, Faculty of Education, North-West University, Potchefstroom, South Africa; Research Unit Self-Directed Learning, Faculty of Education, North-West University, Potchefstroom, South Africa
Email: divan.jagals@nwu.ac.za
ORCID: https://orcid.org/0000-0001-5840-6298

Dr Divan Jagals is a senior lecturer in the School for Professional Studies at the Faculty of Education, North-West University. His research interests include aspects of Mathematics teaching and learning, especially metacognition in Mathematics Education to enhance self-directed learning.

Dorothy Laubscher

School of Mathematics, Science and Technology Education, Faculty of Education, North-West University, Potchefstroom, South Africa; Research Unit Self-Directed Learning, Faculty of Education, North-West University, Potchefstroom, South Africa
Email: dorothy.laubscher@nwu.ac.za
ORCID: https://orcid.org/0000-0002-9067-437X

Dr Dorothy Laubscher is a senior lecturer in Mathematics Education in the Faculty of Education, North-West University. She has been working in the field of education (both secondary and tertiary) for the past 24 years. Her research interests include Mathematics Education, self-directed learning, blended learning and cooperative learning.

Lesley Le Grange

Department of Curriculum Studies, Faculty of Education, University of Stellenbosch, Stellenbosch, South Africa
Email: llg@sun.ac.za
ORCID: https://orcid.org/0000-0002-7096-3609

Prof. Lesley Le Grange is a distinguished professor in the Faculty of Education, Stellenbosch University. He has 218 publications to his credit and serves on the editorial boards of eight peer-reviewed journals. He has delivered more than 160 academic presentations and has received several academic awards and prizes. He is a member of the Higher Education Quality Committee of the Council on Higher Education in South Africa. He has been appointed by the Minister of Higher Education and Training as a member of the Council on Higher Education from 2019. He serves on several National Research Foundation (NRF) panels, is the vice president of the International Association for the Advancement of Curriculum Studies and is a Fellow of the Royal Society of Biology (UK). Lesley is rated as an internationally acclaimed researcher by the NRF. His current research interests are exploring resonances/dissonances between African traditional values and (post)human theories, exploring implications of an immanent ethics for (environmental) education research and decolonising of the curriculum.

Marry Mdakane

Research Unit Self-Directed Learning, Faculty of Education, North-West University, Potchefstroom, South Africa
Email: marry.mdakane@nwu.ac.za
ORCID: https://orcid.org/0000-0003-0724-4457

Dr Marry Mdakane is a Curriculum Studies lecturer at the North-West University. She is affiliated with the Faculty of Education and serves as a member of the Ethics Committee for the Faculty of Education for all three North-West University campuses. Marry has worked in the field of teacher education for the past 13 years. Her areas of research expertise include self-directed learning, indigenous knowledge and open distance learning.

Elsa Mentz

Research Unit Self-Directed Learning, Faculty of Education, North-West University, Potchefstroom, South Africa
Email: Elsa.Mentz@nwu.ac.za
ORCID: https://orcid.org/0000-0002-7267-080X

Prof. Elsa Mentz is the research director of Research Unit Self-Directed Learning at the Faculty of Education, North-West University. She is also a research professor in Computer Science Education and her main research focus is the promotion of Self-Directed Learning through the implementation of cooperative learning. She has acted for extended periods as executive dean of the Faculty of Education, North-West University. She is a National Research Foundation (NRF) rated researcher and editor of the book, *Self-directed learning research: An imperative for transforming the educational landscape*. She received several research awards, including three NRF project grants, a SANPAD project grant, as well as six Vice-Chancellor awards for excellence. She is also the recipient of the Education Association of South Africa's 2020 Research Medal, as well as the Malcolm Knowles Award. She has published at national and international level and acts as supervisor for postgraduate students.

Jako Olivier

UNESCO Chair in Multimodal Learning and Open Educational Resources, Faculty of Education, North-West University, Potchefstroom, South Africa; Research Unit Self-Directed Learning, Faculty of Education, North-West University, Potchefstroom, South Africa
Email: jako.olivier@nwu.ac.za
ORCID: https://orcid.org/0000-0002-5860-6027

Prof. Jako Olivier is the UNESCO Chair in Multimodal Learning and Open Educational Resources and a professor in Multimodal Learning in the Faculty of Education, North-West University (NWU). He joined the NWU in 2010 as a lecturer in Afrikaans applied linguistics after which he moved to Afrikaans language teacher education. In 2018, he was promoted as professor of Multimodal Learning. His research interests include multimodal and blended learning, open educational resources, multiliteracies and self-directed learning, e-learning in the language classroom, language planning and policy, as well as multilingualism in education. He currently holds a Y rating from the National Research Foundation and was awarded the Education Association of South Africa (EASA) Emerging Researcher Medal in 2018.

Neal Petersen

School of Mathematics, Science and Technology Education, Faculty of Education, North-West University, Potchefstroom, South Africa; Research Unit Self-Directed Learning, Faculty of Education, North-West University, Potchefstroom, South Africa
Email: neal.petersen@nwu.ac.za
ORCID: https://orcid.org/0000-0002-4415-2853

Prof. Neal Petersen holds a doctoral degree and is an associate professor in Life Sciences Education in the School of Mathematics, Science and Technology Education (and Deputy Director of the school) in the Faculty of Education, North-West University, Potchefstroom Campus. He has experience in teaching various academic and subject methodology Life Sciences modules. His research interests include active learning, contextualised science education, indigenous knowledge, STEAM education, cooperative learning, self-directed learning and teacher professional development in science education. He is a co-researcher in the research project concerning the infusion of IK into the science curriculum. He is the principal investigator of a project on using engaging pedagogies in science education, including the infusion of arts into STEM education moving towards STEAM education.

Erika Potgieter

School of Mathematics, Science and Technology Education, Faculty of Education, North-West University, Vanderbijlpark, South Africa; Research Unit Self-Directed Learning, Faculty of Education, North-West University, Vanderbijlpark, South Africa
Email: 23423455@nwu.ac.za
ORCID: https://orcid.org/0000-0002-7065-964X

Ms Erika Potgieter is a junior lecturer in Mathematics Education, North-West University. She is currently furthering her studies in Mathematics Education, pertaining to the use of puppetry in the Intermediate Phase. Her research is nested in metacognition and reflection, especially for teacher professional development.

Tswakae Sebotsa

School of Mathematics, Science and Technology Education, Faculty of Education, North-West University, Potchefstroom, South Africa; Research Unit Self-Directed Learning, Faculty of Education, North-West University, Potchefstroom, South Africa
Email: 28957210@nwu.ac.za
ORCID: https://orcid.org/0000-0001-7839-0190

Mr Tswakae Sebotsa is a Physical Sciences lecturer in the Faculty of Education, North-West University. He is working in the field of science education, and his research niche encompasses the epistemological border-crossing between Western science, indigenous knowledge and the arts, and the affordances of indigenous knowledge in the science classroom. He attended a course on Aesthetic Education Immersion at the Lincoln Centre in New York to explore the role of arts in the Natural Sciences.

Melissa Speight Vaughn

Research Unit Self-Directed Learning, Faculty of Education, North-West University, Potchefstroom, South Africa; Research Unit Self-Directed Learning, Faculty of Education, North-West University, Potchefstroom, South Africa
Email: mspeightvaughn@gmail.com
ORCID: https://orcid.org/0000-0003-4475-0834

Dr Melissa Speight Vaughn is a postdoctoral fellow in the Faculty of Education, North-West University. In addition to 10 years of experience as a public school teacher, she has conducted qualitative community-based research in the United States, Belize, Central America and South Africa. Research specialisations include cultural and indigenous ways of knowing, citizenship praxis and research ethics.

Marthie van der Walt

School of Mathematics, Science and Technology Education, Faculty of Education, North-West University, Potchefstroom, South Africa
Email: marthie.vanderwalt@nwu.ac.za
ORCID: https://orcid.org/0000-0002-0465-6600

Prof. Marthie van der Walt is an associate professor in the Faculty of Education, North-West University. She has been working in the field of Mathematics teacher education for the past 20 years, and her research niche encompasses metacognition as reflective methodology for Mathematics teachers' professional development and the affordances of contextualising Mathematics topics in Indigenous Knowledge (games, music and puppetry) to make Mathematics more meaningful and accessible to all learners. She developed the *Tshimologo Mathematics Shoestring Kit* to support the contextualising of Mathematics in IK (games, music and using puppetry) and presented to participant teachers in 2018.

Christo van der Westhuizen

School of Mathematics, Science and Technology Education, Faculty of Education, North-West University, Potchefstroom, South Africa; Research Unit Self-Directed Learning, Faculty of Education, North-West University, Potchefstroom, South Africa
Email: christo.vanderwesthuizen@nwu.ac.za
ORCID: https://orcid.org/0000-0002-4762-8538

Prof. Christo van der Westhuizen is currently associate professor in Geography & Environmental Education in the School of Natural Sciences and Technology for Education in the Faculty of Education Sciences, North-West University, Potchefstroom Campus. He has been working in the field of teacher education for the past 17 years, and his research focus is on the effective integration of information and communication technology (including geospatial technologies) in Geography Education as well as in blended and digital learning environments to foster self-directed learning. He is an editorial board member of the *Journal of Geography in Higher Education (JGHE)*.

Ben-Erik van Wyk

DST-NRF South African Research Chair of Indigenous Plant Use, Department of Botany and Plant Biotechnology, Faculty of Natural Sciences, University of Johannesburg, Johannesburg, South Africa
Email: bevanwyk@uj.ac.za
ORCID: https://orcid.org/0000-0003-0306-8193

Prof. Ben-Erik van Wyk is the DST-NRF South African Research Chair in Indigenous Plant Use (2013–2022) and is associated with the Department of Botany and Plant Biotechnology at the University of Johannesburg. His field of expertise is plant taxonomy and ethnobotany. He has authored and co-authored more than 300 research papers in accredited scientific journals, as well as 20 national and international books. Awards include the 2006 Havenga Prize for Biology from the South African Academy of Science and Arts, the UJ

Faculty of Science Award for Top Researcher of the Year (2009, 2011, 2014 and 2017), a medal (*erepenning*) from the South African Academy of Science and Arts for contributions to ethnobotany in South Africa (2011) and the SAAB Silver and Gold Medals from the South African Association of Botanists for contributions to botany in South Africa (in 2007 and 2013, respectively). Ben-Erik is a Fellow of the African Academy of Sciences.

Lounell White

School of Mathematics, Science and Technology Education, Faculty of Education, North-West University, Potchefstroom, South Africa
Wmail: lounell.white@nwu.ac.za
ORCID: https://orcid.org/0000-0002-8243-339X

Dr Lounell White is a senior lecturer in Life Sciences in the School of Natural Sciences and Technology for Education in the Faculty of Education, North-West University, Potchefstroom Campus. Her research interests include the affordances of indigenous knowledge in the science classroom and the use of engaging pedagogies in science education.

Acknowledgements

The cover photograph

The Carnarvon region of the Northern Cape, South Africa, is an interesting place. The cover photograph juxtaposes the oldest indigenous knowledge system in the world – that of the San, which has its roots in this area – with the most advanced science and technology in the world in the square kilometre array (SKA) radio telescopes in the same region. The science teacher is confronted with the challenge of preparing future scientists for a complex 21st century in which science is central, yet contextualising science through the infusion of the rich indigenous knowledge that characterises the Rainbow Nation.

We would like to thank Dr Anton Binneman, the NRF and the South African Radio Astronomy Observatory (SARAO) for permission to use this photograph.

Thanking our sponsors

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Foreword

Robert J. Balfour
Deputy Vice-Chancellor: Teaching–Learning,
North-West University,
Potchefstroom, South Africa

This book represents a powerful act of scholarly reclamation, restoration and redress. By locating the text within the nascent scholarship concerning the decolonisation of the curriculum (in fields beyond postcolonial literary studies), and positioning Indigenous Knowledge Systems (IKS) as a means through which curriculum and curriculum making, pedagogy and teaching methodologies come to be revisioned, the book makes a powerful, compelling and scholarly case for the imperative to deepen the educational engagement with transformation, for teachers, learners and faculty.

The three concepts (reclamation, restoration and redress) echo powerfully in scholars' accounts of the contexts making us aware of the importance of IKS, not only as ways of knowing but also as ways of being and seeing. Reclamation is both restorative and recentring. It aims to restore indigenous to its rightful place in Social Sciences as well as the Natural and Physical Sciences. By doing so, it does not fetishise how we understand the word 'indigenous' as a historical curiosity, or pseudoscience or merely as an illustration of what some might consider to be a more substantive (and invariably Western) body of knowledge. Indigenous, in this sense, refers to knowledge arising across a variety of communities and knowledge that is both past and present, that is retrospective and prospective, that is simultaneously scientific and social, that is tangled and yet clearly traceable and tangible. Indigenous, when viewed from this perspective, concerns also the dignity of reclaiming social and

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academic space for communities' knowledge-making approaches, be this through knowledge retrieved or knowledge created anew through the lived experience of groups of people considered as, or who experience themselves as, marginal from the construction, deconstruction and knowledge production project.

This book reclaims for scholarly endeavour, sources of knowledge long excluded from higher education as well as the school curricula. Tracing the colonial origins of the marginalisation of Indigenous Knowledge (IK), the text simultaneously illustrates what IK is, why it matters and indeed, in many instances in postcolonial contexts like South Africa, why it matters more than either the history of its displacement or the academic traditions to which it seeks to contribute. Two points are relevant here; firstly, the project concerning IK, its definition, practice and its ontologies and epistemologies need to be centred, placed and (re)located within our understanding of what knowledge is, what functions it serves and might yet serve, as well as to which communities (of scholars, of society) it contributes – again, neither as derivative nor as ancillary to, but as important as what the academy considers worthy in the present as well as in the future. Secondly, the historic refusal to engage with IK, either in terms of curriculum development or innovation, or in terms of scholarly contribution to the world's body of knowledge, is not simply about rejection or marginalisation of a body of knowledge but also about what matters, whose lives matter less or more, who is considered to be less important than, or somehow adjacent to, the cosmopolitan and urban Western subject, assumed for too long to be the normative standard by which all self-imagined 'others' are measured.

Indeed, in the context of the classroom, the very notion of Western and non-Western are revealed as useless categories whose existence as distinct and mutually exclusive domains are demonstrated (through the close correlations described between Western scientific approaches and those approaches used by communities to describe, verify, classify and theorise knowledge) and revealed to be colonial fictions, the uses of which have long been known to be damaging and divisive to human consciousness. Seen in this light, the book also represents scholarly restitution – the (re)membering of a body of knowledge originating across the globe, in different spaces and times and yet fascinating in its processes of formation and reformulation; a body of knowledge that refuses the claims of belonging exclusively to one group or another to justify the unjustifiable: a hegemony which others while it simultaneously extracts value. In the manifold acknowledgements of the scientific, pedagogic and social value of IK, this book seeks to restore to both the communities and the academy a body of knowledge that adds value to the dignity of human beings as contributing equally, even if in different ways, to knowledge. Using a range of qualitative and quantitative methodologies, the research contribution of this book to the transformed knowledge project is of immense value, as it prompts the reader to reconsider assumptions regarding the very ways in which we think about thinking, how we define knowledge and to what purposes we instrumentalise it.

Chapter 1

Glocalisation: The role of indigenous knowledge in the global village

Josef de Beer
Research Unit Self-Directed Learning, Faculty of Education,
North-West University, Potchefstroom, South Africa

Introduction

I would like to start this chapter with two short vignettes, the first of a more personal nature and the second spawned by the 2016 student unrests that erupted on university campuses across South Africa. These two eclectic pieces remind me of Don Beck and Linscott's (1991) view that South Africa, with its cultural diversity and inequalities, could serve as the world's laboratory. If we can, within this crucible which is South Africa, find solutions to the perennial issues that we face, we could provide the world

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with a blueprint for solving similar problems elsewhere on the globe. And this is the essence of this book. The book reflects on research data on attempts of decolonising the curriculum through the infusion of IK into the Science, Technology and Mathematics curricula. It is hoped that these insights could also be relevant elsewhere in the world, and that, in an era of 'glocalisation' (Patel & Lynch 2013), we can also export educational solutions based on research.

The first vignette dates back to 2009, 15 years after South Africa became a democracy. I submitted a paper on IK to *The American Biology Teacher* (ABT) journal. The paper, co-authored with Elrina Whitlock, focussed on the epistemological border-crossing when IK is infused into the Life Sciences curriculum, and how an adapted Kirby–Bauer technique could be used to test the antimicrobial properties of medicinal (*muthi*) plants (De Beer & Whitlock 2009). This paper was an attempt to infuse IK into the school curriculum to capitalise on the tenets of the Natural Sciences. Most scholars occasionally receive a bad peer review. However, *bad* is probably a euphemism in this case. The editor of ABT in those days, Ann Mackenzie, sent me two peer review reports, with a note that she would like to publish the piece, but not before I address the concerns of one reviewer. Fortunately, I started reading the positive report of the two, which hailed the innovation of using the processes of science to introduce IK in the Life Sciences school curriculum. My excitement quickly diminished when I read the second report. Quite frankly, the words hit me like bullets. 'These authors advocate witchcraft which seems to be popular in the impoverished, illiterate and superstitious South Africa' (Reviewer, undisclosed gender, date unknown). It took me several days to gain the courage to engage with the reviewer's comments and to scrutinise the manuscript for any traces of what could be considered 'pseudoscience'. However, this made me realise that there are many academics who view IK with scepticism. Later, I realised that there are also plausible arguments against the infusion of IK into the Natural Sciences school curriculum. Onwu and Mosimege (2004) show that there are big differences in the epistemologies and methodologies of, respectively, Western science and IK. The latter authors 'are of the opinion that it would be [a mistake] to subject indigenous knowledge [...] to the same verification [processes] as [Western] science' (De Beer & Petersen 2017).

In sharing the second vignette, I need to give credit to Lesley Le Grange. When I read his chapter on the decolonising of the curriculum (Ch. 2), I was moved by Gillian Schutte's impression (captured in Lesley's chapter) of the incident where three women students exposed their breasts during the 2016 student unrests on the campuses of our Higher Education Institutions (HEIs), when they were confronted by armed policemen. Here is Gillian's (2016) account:

> They looked brave and vulnerable. Their naked stomachs and breasts juxtaposed with police in riot gear armed with guns had a profound effect on all. The stark contrast was shocking and rendered the violence of men with guns and riot gear hyper-visible. Naked flesh exposed on the site of violence makes a visceral anti-war statement and this was war. It was a war declared by state and institution against the black child who dared to rise for their rights. Many dismiss the women's naked protest. They bemoaned the fact that yet again black women were forced to lose their dignity by stripping naked. But nakedness is not a loss of dignity when voluntarily used in protest. It is resistance against those who would strip them of their dignity. Women's breasts are a powerful semiotic of resistance. Breasts are the most vulnerable part of their bodies. They are also a source of nurturing. Even men with guns have been nourished on their mother's breasts. Breasts are both robust and vulnerable. These three half-naked women disarmed the police with their naked cries. The police did not fire their guns again. (n.p.)

Both vignettes speak of marginalisation – ostracised knowledge systems in the first case, where the indigenous is seen as inferior to what Mbembe (2016:32) calls a 'Eurocentric epistemological canon'. The second scenario speaks of students who might have physical access to tertiary studies, but not necessarily epistemological access. The 'decolonisation of the curriculum' debate is often coloured in political undertones. Although the above vignettes might seem unrelated at first read, there is actually a thread connecting them (De Beer & Whitlock 2009):

> Under provisions of the *Suppression of Witchcraft Act of 1957*, first introduced in 1895, all forms of divination [– *which is at the heart of healing practices in Africa*] were outlawed. (p. 210)

Indigenous Knowledge (IK) was marginalised. This has led to a phenomenon that the Kenyan scholar Wa Thiong'o (1986) refers to as the 'colonisation of the mind'. When the students were protesting during the #FeesMustFall campaign, it was about more than just free education. It was fuelled by conditions of structural disenfranchisement experienced by 'students who [wanted] access to opportunities to improve their lives' (Disemelo 2015 cited in De Beer & Petersen n.d.:449). This discourse is discussed in detail in Chapter 2.

However, this book argues for 'the inclusion of indigenous knowledge from a perspective [of neuroscience and] learning psychology' (Jautse, Thambe & De Beer n.d.:442). It is argued that IK, when infused into the curriculum, could, firstly, better contextualise the prescribed learning content for South African learners. I need to state upfront that the point of departure is that the substantive nature of (school) subjects – the principles, theories and 'unifying themes' that have always characterised it – is still considered the 'backbone', but we argue that infusing IK into it will provide contextualisation that will provide epistemological access to learners. Secondly, De Beer and Mentz argue that it could also enhance self-directed learning. In Chapter 4, these authors provide a justification for this statement.

The chapters in this book stem from funded research, and we would like to acknowledge the support of the National Research Foundation (NRF) and the Fuchs Foundation. Most of the chapters stem from Design-based Research (DBR) conducted from 2016 to 2018. Later in the chapter, I also provide an insight into the shortcomings of the project thus far and discuss the new phase that the project is embarking on, namely, the use of change laboratories (Virkkunen & Newnham 2013) to obtain buy-in from all stakeholders in the SLPs offered thus far.

This DBR project should be viewed in the context of the challenges South Africa faces in terms of teacher professional development. When we conceptualised the project, we were guided by the principles outlined for teacher professional development in the report by the Centre for Development and Enterprise (CDE 2011:22–23), namely:

- Short workshop-type professional development is not effective.
- There should rather be a focus on a number of key outcomes or instructional priorities over a longer period of time.
- For effective teacher learning, actual school and classroom data should be utilised.
- The most successful learning occurs when teachers engage with each other, and the experts (teacher educators) should act as 'critical friends' in scaffolding learning.
- Teachers should be immersed in enquiry, Problem-based Learning (PBL) and experimentation.
- The focus of teacher professional development interventions should include both Subject Matter Knowledge (SMK) and Pedagogical Content Knowledge (PCK).
- Such teacher professional development should take place in the context of whole-school development.

Chapter 2 to Chapter 11, despite their slightly eclectic nature, speak of the above-mentioned principles in one way or the other.

In Chapter 2, Lesley Le Grange looks at the different perspectives on the decolonising of the curriculum debate. He interrogates the tensioned space between the *curriculum-as-plan* and the *curriculum-as-lived* and argues that it is a space of struggle, creativity, transformation and, notably, decolonisation. Lesley also touches upon the concept of *null curriculum*, which, among others, refers to IK not being taught in formal education. The chapter also addressed *curriculum experimentation,* an aspect that is addressed in most of the chapters of this book.

As Cultural-Historical Activity Theory (CHAT) is used as a research lens in several of the chapters in this book, Elsa Mentz and Josef de Beer explore the affordances of third-generation CHAT in Chapter 3. The chapter sheds light on the versatility of third-generation CHAT as a qualitative research lens, and the authors show how it can be used on a personal, interpersonal and institutional plane. By way of illustration, the authors juxtapose two different activity systems – SLPs for teachers on IK in the Northern Cape and Limpopo provinces – to show that there are multiple factors that influence the success of teacher professional development programmes. Cultural-Historical Activity Theory provides a unique insight into the difficulties of epistemological border-crossing between Western science and IK.

The premise of Chapter 4 is that the holders of IK were, and still are, self-directed learners. De Beer and Mentz show, by referring to Ethnobotanical Knowledge Index (EKI) data (De Beer & Van Wyk 2011), that learning about useful plants in the Namaqua district by people of Khoi-san descent was directed at solving authentic problems. A second example of subsistence livestock farmers in the Vhembe district in Limpopo is used as an example of self-directed learning. The chapter concludes by looking at the lessons that these insights hold for formal science education in South Africa. The dominant culture of 'teaching-to-the-test' does not adequately prepare learners for the demands of a complex 21st century, and these authors argue that the holders of IK hold several keys to improving teaching and learning in our schools.

In Chapter 5, Josef de Beer and Ben-Erik van Wyk navigate the chasm between arguments for and against the inclusion of IK in the science, technology and Mathematics curriculum. The chapter sheds light on neurobiology research and argues for the inclusion of IK from an embodied, situated and distributed cognition perspective. One of the objections to such border-crossing is that teachers often view IK as 'pseudoscience', owing to its holistic and often metaphysical nature. The authors use several examples from ethnobotany to show that there are often scientifically plausible explanations for what at first sight seems like ‘magical’ plant use. Gorelick (2014:43) states that ‘often indigenous sciences are construed as pseudoscience, despite being as sophisticated and nuanced as Western science’. The fact that indigenous science is often characterised by the embracement of metaphors sheds light on many of the puzzling vignettes that make people wonder.

In Chapter 6, Neal Petersen, Aubrey Golightly and Washington Dudu focus on research data obtained during three cycles (2016–2018) of SLPs offered to Natural Sciences teachers, where the focus was on the professional development of teachers to effectively infuse IK into the school curriculum. Their findings pave the way for future interventions to ensure that science teachers have more nuanced understandings of, respectively, the Nature of Science (NOS) and IK. An aspect that is emphasised is that supportive communities of practice are needed, to ensure the success of teacher professional development interventions.

Chapter 7, authored by Marthie van der Walt, Erika Potgieter and Divan Jagals, explores research in the field of ethnomathematics. The SLPs for teachers that are the focus of their research use Pedagogy of Play (PoP), and through the engagement in indigenous African games, and making music, Mathematics concepts are dealt with. The authors share major themes that were elicited from the research that spanned a period of three years. One of the central themes that emerged from the research is the affordances of ethnomathematics to enhance the affective domain, and to improve learner motivation and enjoyment of Mathematics.

The focus in Chapter 8 shifts to Indigenous Technology (IT). Marietjie Havenga uses CHAT as a lens to contextualise IT in problem-based environments. As in Chapters 6 and 7, she also shares research findings emerging from technology teachers’ engagement in an SLP on IK. One of the problems highlighted is the so-called wash-out effect, where teachers often abandon new innovative pedagogies to fall back on 'chalk-and-talk' approaches.

Recently, Science, Technology, Engineering and Mathematics (STEM) education made way for STEAM, the 'A' being arts. In Chapter 9, Lounell White, Susan Bester and Tswakae Sebotsa explore the affordances of puppetry in education, to teach IK. Puppetry as pedagogy builds on storytelling, which is also a characteristic of IKS. The authors therefore argue that puppetry is an effective way of engaging learners in IK. They share research findings on student teachers' experiences of engaging with puppetry. The chapter underlines several capacities of imaginative thinking (Lincoln Centre 2018) that are equally relevant in science and arts, such as to observe deeply, to pose questions and make connections, and to live with ambiguity.

Chapter 10 deals with the affordances of technology for teaching IK. Jako Olivier, Christo van der Westhuizen, Dorothy Laubscher and Roxanne Bailey explore the use of technology to embed IK in different subjects while adhering to blended, e-learning and self-directed learning principles. The chapter offers a critical literature review, and also provides innovative solutions in terms of technology use to enhance both IK and self-directed learning.

The San Code of Research Ethics is the first indigenous code of researcher ethics in South Africa. In Chapter 11, Melissa Speight Vaughn and Marry Mdakane investigate research ethics in the field of IK, and the alignment between research ethics as captured in policy documents at HEIs (Western universality) and the San Code of Research Ethics. Postcolonial indigenous theory and discourse analysis theory comprise the theoretical framework for their chapter. They quote Andries Steenkamp (n.d.:n.p.), a San leader, saying, 'come through the door not the window'.

I trust that the chapters in this book will spur further research on the role of IK in STEM education and its affordances for self-directed learning.

The design-based research: Looking back; looking forward

This DBR project was funded by the NRF and the Fuchs Foundation. Design-based research is rooted in pragmatism (Hogue 2013), as it aims to find solutions to educational problems in authentic settings. Design-based research serves the dual purpose of assisting in the development of innovative learning interventions, as well as contributing to new theoretical insights into education (Hung 2011). It entails repeated cycles of design, implementation, analysis and revision (Greyling 2007). The research reported on in this book spans three cycles, over a period of three years. After each cycle, design principles were elicited based on our research data and feedback from the teachers who participated in earlier SLPs. These design principles informed the next cycle. In this way, we tried to continuously improve upon the SLP, based on experiences from the preceding SLPs. Herrington et al. (2007:2) mention that 'design-based research should address complex problems in real contexts in close collaboration with practitioners'. This description provides a good litmus test to assess the achievements and shortcomings of the project, as well as determines the future direction.

Addressing a complex problem

Science education in South African schools leaves much to be desired, as is illustrated in international benchmark tests such as the Trends in Mathematics and Science Study (TIMSS). There are several reasons for this poor performance. The CDE (2011) makes it clear that no schooling system can rise above the limits imposed by the quality of its teachers. There is, therefore, a need for the country to invest in teacher education. De Beer (2016) is of the opinion that another reason for this poor performance, which is often overlooked, is the marginalisation of the affective domain. Science themes in the curriculum are often not perceived as relevant or interesting to the learners. Very often, learners find it difficult to see how the world of science relates to their everyday lives.

The inclusion of IK could serve as a bridge between science and everyday life (De Beer 2016). However, research conducted by, among others, Mothwa (2011) and Cronje (2015) shows that most South African teachers do not have the knowledge or skills to effectively implement IK in Science and Mathematics lessons. The chapters in this book report on a DBR project, spanning over three years, in which Science, Technology and Mathematics teachers were exposed to the affordances of IK in the classroom.

Authentic contexts and glocalisation

Learners do not enter the classroom as *tabula rasa*; they come with cultural knowledge based in the environments in which they live. The SLPs, which we report on in this book, were developed to show teachers as to how they could capitalise on this IK, using innovative teaching methods, such as PBL and Cooperative Learning (CL). Such authentic contexts, we argue, can make science more accessible and interesting to learners. Chapter 5 argues the affective affordances of such an approach from the perspective of embodied, situated and distributed cognition (Hardy-Vallée and Payette 2008).

However, there is no consensus among scholars with regard to the inclusion of IK in the STEM school curriculum. Taylor and Cameron (2016) and Zinyeka, Onwu and Braun (2016) proposed three different perspectives on the relationship between Natural Science and IK.

Firstly, the inclusive perspective views IK as part of science. I personally only partly agree with this perspective. There are several shared tenets between Western science and IK, for example, both are empirical, tentative and inferential (refer to

Chapter 6 by Petersen et al. for more detail). However, there are also differences between the two – for example, IK is holistic and also includes metaphysical aspects, whereas these do not have a place in the Natural Sciences (refer to Ch. 5 by De Beer and Van Wyk for an in-depth discussion on this). We did not address the metaphysical aspects in the SLPs.

Secondly, the exclusive perspective sees IK and Natural Science as two different epistemologies. Onwu and Mosimege (2004) are of the opinion that it is not wise to subject IK to the same verification techniques used in the Natural Sciences:

> I don't think we should be looking at IKS with the same lens of judgment as we would with Western science. When I say this I am not suggesting that we should just accept without questioning or verification the rigorous standards that tend to be used in the Western system. In fact, IKS or some of the components thereof have equally rigorous standards of validation and measures that also characterise it. I am suggesting that the two systems are different and therefore require different forms of verification. These verification methods and processes can actually be equated and be made to be similar standards, however they have to be appropriate for each system, otherwise we would compromise one system at the expense of another and in the process lose the beauty of what the two systems could provide alongside each other. (p. 6)

We parted from such a perspective, in favour of the third perspective. However, we acknowledge the plea that IK should be appreciated in its uniqueness.

Thirdly, in our SLPs, we followed an approach based on a third perspective, which views Natural Sciences and IK as having intersecting domains. We have, therefore, exclusively focussed on aspects of IK that are based on empirical work. Cronje (2015:37–39) showed that Western science and IK share several tenets, for example, both acknowledge that nature is real, observable and testable (its empirical nature), and that both science and IK are constantly changing, and therefore transformative (its tentative nature). Furthermore, both are creative (observations and experiments are not the only sources of scientific knowledge).

One example of a learning activity, based on these shared tenets, is the Kirby–Bauer laboratory protocol, which was used in the SLPs. This learning activity requires teachers to test whether traditional *muthi* plants have antimicrobial properties (see Ch. 5). This activity demonstrates how science and IK are based on shared tenets. Teachers explored IK using integrated process skills (Sanders 2010), such as designing and conducting experiments and interpreting data. Another example used in the SLPs was soap making. Various indigenous plants contain saponins, which dissolve fat and oily substances (Van Wyk & Gericke 2018). This can provide an excellent activity for the chemistry classroom. The caustic alkali (such as sodium hydroxide) can be replaced by the lye ash from 'soap plants' such as the *seepganna* (*Salsola aphylla*) or the *asbos* (*Mesembryanthemum junceum*) (Van Wyk & Gericke 2018). The lye converts the fat or oil into soap through a process known as 'saponification'. In Figure 1.1, science teachers engage in a soap-making activity during a Short Learning Programme (SLP).

Source: (a & b) Photographs taken by Josef de Beer, specific date and location unknown, published with permission from Josef de Beer and the written consent of Mr Pule and Mr Sebotsa.

FIGURE 1.1: (a) Teachers learn about saponification and (b) two of the researchers, Mr David Pule and Mr Tswakae Sebotsa, inspect the soap that the teachers made.

Such authentic contexts also provide a platform for *glocalised teaching and learning*. Patel and Lynch (2013) define glocalised learning and teaching as:

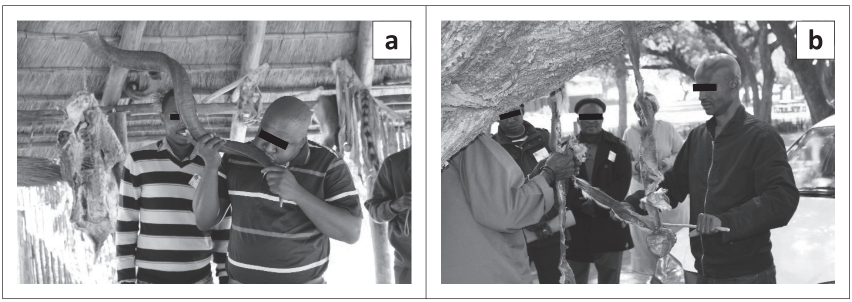
> [*T*]he curricula consideration and pedagogical framing of local and global community connectedness in relation to social responsibility, justice and sustainability [...] blending and connecting local and global contexts while maintain[*ing*] the significant contributions of the different communities and contexts. (p. 223)

Glocalisation builds on the notion of 'third culture building' (Patel & Lynch 2013:224), which entails an exchange of cultural wealth (cultural ideas, knowledge, stories, approaches to the cultivation of food, etc.). Glocalisation is a holistic perspective, which rejects ethnocentric agendas for such third culture building. Let me illustrate this by means of a practical example. Research literature (Aktar, Sengupta & Chowdhury 2009) highlights the potential risks of insecticides to the health of humans and other life forms, as well as to the environment. Insecticides are, therefore, an issue of global importance. Indigenous knowledge holders in the Giyani district in the province of Limpopo have provided an environmentally friendly solution to potentially dangerous pesticides. The predominantly Tsonga people in Giyani have been using the fever tree (*Lippia javanica*) as an insect repellent for decades (De Beer 2015). The Council for Scientific and Industrialised Research (CSIR) is working with the local community in Giyani and has registered a patent on the use of *Lippia javanica* as an insect repellent. The community members are involved in making candles using the oils of the fever tree. The volatile oil of the plant contains myrcene, caryophyllene, linalool and ipsdienone, and research has shown that *Lippia javanica* extracts compare well in terms of efficacy with Diethyltoluamide (DEET), the best-known commercial mosquito repellent (Van Wyk & Gericke 2018), but without the side effects of DEET. This is an example of localised (indigenous) knowledge, with global application.

Van Wyk and Gericke (2018:7) are of the opinion that a new era has dawned, where collaborations are established between government departments, science councils, universities, traditional healers, local communities and entrepreneurs, in finding collective solutions to problems that humankind faces. The results of this effort are several natural products that are already available in local and international markets.

Collaboration with practitioners

The holders of IK were involved in the conceptualisation of the SLPs. For example, we worked with IK holders at the Bakone Malapa open-air museum in Polokwane, for the Limpopo SLP. For the SLPs in the North-West province, we again consulted IK holders at the Mphebatho Museum in Moruleng, in the Pilanesberg. For our work in the Namaqua district in the Northern Cape, we consulted with the curator of the Calvinia Museum. The museums became the 'third partner' in the value chain between universities (offering the SLPs) and schools (where teachers have to transfer the new knowledge and skills) (Mathews & McArthur 2004; Jautse, Thambe & De Beer 2016). Jautse et al. (2016) opine that teacher educators do not necessarily understand IK or have the skills to effectively facilitate SLPs. The involvement of the holders of IK and museums could, therefore, enhance the quality of such offerings. In Figure 1.2, science teachers engage in activities such as leather tanning at IK museums, under the guidance of IK holders.



Source: (a & b) Photographs taken by Josef de Beer, specific date and location unknown, published with permission from Josef de Beer and the written consent of the participating teachers.

FIGURE 1.2: Working with IK holders at the (a) Bakone Malapa Museum in Polokwane and the (b) Mphebatho Museum in Moruleng.

When we analysed the data after the SLPs, we realised that we should have consulted more widely. Parents, school principals and officials from the Department of Basic Education should also have been consulted. From the data (presented mainly in Ch. 3 and Ch. 6), it became clear that there is pressure on teachers to prepare the learners for summative assessment, and this results in many of the goals of the SLP (such as the teaching of IK through PBL and CL approaches) not being transferred to the classroom. Addressing this constraint has been set as a goal for future interventions and research, where we plan to make use of change laboratories. In Chapter 3, Mentz and De Beer discuss the use of third-generation CHAT as a research lens. These authors are currently planning change laboratories and shifting gear towards fourth-generation CHAT in the research on the SLPs.

The effectiveness of the short learning programmes: Successes and challenges

The data prove that the SLPs were successful in providing the majority of the teachers with improved knowledge and skills related to epistemological border-crossing between science and IK, and learner-centred methods such as PBL and CL. As the research data are dealt with in several of the chapters of this book, I will not repeat this point here. (Refer to Ch. 3 and Ch. 6 for themes emerging from the Natural Sciences SLPs; Ch. 7 for the findings from the Mathematics SLP; and Ch. 8 for perspectives in terms of technology education.) However, we realised, much to our own disappointment, that transfer of knowledge and skills did not occur in many classrooms after the SLP. Several of the teachers reverted back to the traditional chalk-and-talk approaches that they used prior to the intervention. This is an aspect that the researchers will pursue in the next phase of the project. We will follow a two-pronged approach. Firstly, we will use both a longitudinal and systemic approach, supporting online communities of practice, although our attempts in engaging teachers in such online communities of practice have not been very effective thus far (refer to Ch. 10). Secondly, we plan to use change laboratories, in which various stakeholders will be involved (Mentz & De Beer 2019b).

Change laboratories and fourth-generation Cultural-Historical Activity Theory

Involving all stakeholders

As mentioned earlier, our research data (as provided in Ch. 2 to Ch. 11) make it clear that transformation (in terms of teacher professional development) 'cannot be controlled but need[s] to be influenced and shaped' (Virkkunen & Newnham 2013:xvi). Higher education institutions often conceptualise teacher professional development or SLPs according to the insights of the teacher educators at the HEIs, with little or no inputs from teachers themselves, or from other stakeholders such as the Department of Education, school management teams, parents or the school learners themselves. In the SLPs that are discussed in Chapter 2 to Chapter 11, we have made the mistake of marginalising some stakeholder voices in the conceptualisation of the SLPs. Although we did consult with holders of IK and museums, we failed to involve officials from the Department of Basic Education (e.g. the subject advisors), principals, parents or learners sufficiently. We are reminded of the wisdom of Bronfenbrenner (1977), who stated that:

> [*R*]esearch on the ecology of human development should include experiments involving the innovative restructuring of prevailing ecological systems in ways that depart from existing institutional ideologies and structures by redefining goals, roles and activities and providing interconnections between systems previously isolated from each other. (p. 528)

Although the project was successful in providing teachers with the knowledge and skills to infuse IK into the STEM classroom using PBL and CL, we saw limited success in the transfer of such knowledge and skills into the classroom. We have realised that there are factors, such as the expectations of parents and school principals that learners should be well prepared for summative assessment opportunities, that can lead to an erosion of the goals set by the SLP. Likewise, our data show that teachers are of the opinion that the work schedule ('pace-setters') provided by the Department of Basic Education often prevents them from engaging with more learner-centred approaches, as they perceive traditional teacher-centred approaches (chalk-and-talk) as more effective in preparing learners for examinations. This finding is also highlighted in research by Ramnarain and Schuster (2014), who state that:

> [*T*]he culture of the school and parental expectations played a role in shaping the pedagogical orientation of the teachers. The generally poor performance in national science examinations of students at township schools has led to a strong teaching focus towards preparing for high-stakes summative examinations. (p. 648)

Although principals and parents might appreciate IK, or the affordances that CL holds, they do not necessarily see how it can contribute to better performance by the learners.

Change laboratories and expansive learning

In order to address the constraints discussed in the 'Change laboratories and fourth-generation Cultural-Historical Activity Theory' section, Mentz and De Beer (see Ch. 3; Mentz & De Beer 2019b) are currently in the planning phase of implementing a change laboratory, which has also been referred to as a 'border-crossing laboratory' (Engeström 2001:154). The change laboratory is a method that is embedded in the theory of expansive learning (Engeström 2001). Engeström and Sannino (2012) describe expansive learning as:

> [*L*]earning processes in which the very subject of learning is transformed from an individual to a collective activity system or a network of activity systems. Initially individuals begin to question

> the existing order and logic of the activity. As more actors join in, a collaborative analysis and modelling of the zone of proximal development are initiated and carried out. Expansive learning leads to the formation of a new, expanded object. (p. 51)

This collective learning, therefore, includes all the stakeholders, and it assists the group of practitioners in presenting alternative conceptualisations (Engeström 2001).

Very often, teacher professional development is implemented as a 'top-down' intervention, where HEIs plan interventions almost in isolation. Such an approach disregards the essential elements of communication, negotiation and collaboration with all stakeholders (Virkkunen & Newnham 2013). Mentz and De Beer (2019a) opine that there is not always good alignment between the national school curriculum (the Curriculum and Assessment Policy Statement [CAPS]) and the work schedule (or pace-setter) provided to teachers. Whereas IK is acknowledged as a principle underpinning the CAPS, and emphasis is placed on PBL and CL in the curriculum document, the pace-setter often makes it difficult to address these aspects because of time constraints. Teachers involved in our SLPs often state that the pace-setter is the reason why they do not engage in PBL and CL methods, even after they have witnessed the benefits of these approaches during the SLP. These 'tensions' are pointed out in Chapter 3 on CHAT. During a change laboratory, teachers will have the opportunity to discuss their concerns with officials from the Department of Basic Education, and together they can then explore alternatives and solutions (Mentz & De Beer 2019b).

In Chapter 3, Mentz and De Beer claim that there is often a 'contradiction of control' (McNeil 2013) in terms of the object of the activity system (the professional development aims of the SLP). Although the teachers were generally excited to implement the new knowledge and skills in their classrooms after the SLP, they claimed that the expectations of the Department of Basic Education, as well as the pace-setters, prevented such implementation. Change laboratories, where teachers, school principals and officials from the Department of Basic Education jointly discuss a problem, and collectively work towards finding solutions, might, in the long run, provide better outcomes.

Virkkunen and Newnham (2013) state that:

> [*A*] formative Change Laboratory intervention entails successive cycles of identifying and formulating problems, questioning previous problem formulations and conceptions in the search for the core source of problems in the current structure and principle of carrying out the activity. A solution is sought for through an expansive reconceptualization of the object of the activity. (p. 9)

Virkkunen and Newnham (2013:10) emphasise that a change laboratory does not exclusively aim to produce an intellectual solution to a problem but to build 'collaborative transformative agency and motivation'. Engeström et al. (1996) explain that the method used in a change laboratory is based on the principles of re-mediation and dual stimulation, which are derived from CHAT. The dual stimulation means that the task 'is always interpreted and reconstructed by the subject by means of his or her internalized "psychological instruments" that cannot be strictly controlled from the outside' (Engeström et al. 1996:7).

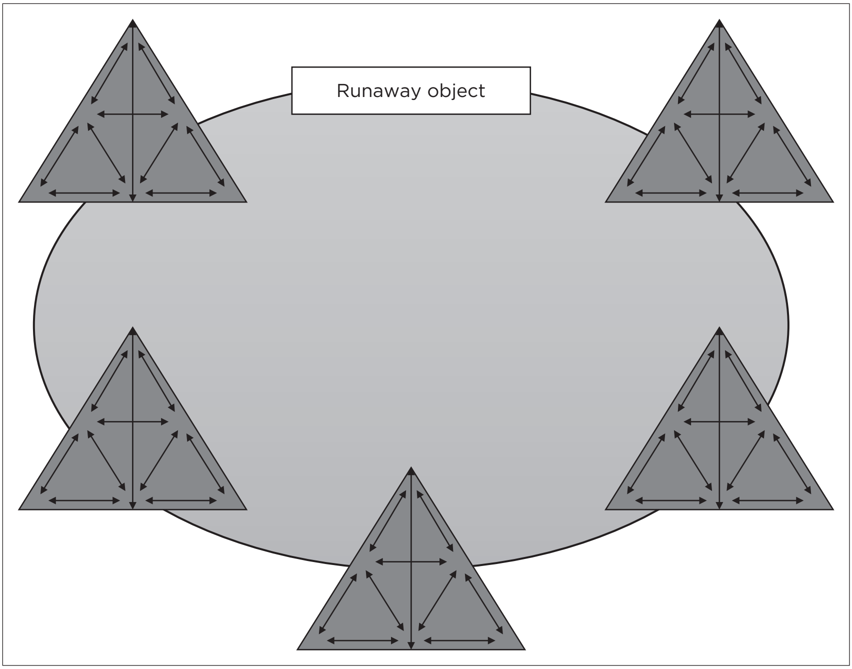
The researchers will, in future, strive to involve subject advisors, curriculum developers, school principals, parents, learners and teacher educators, in finding solutions to the 'contradictions of control' that the CHAT analysis has identified in our research.

Fourth-generation Cultural-Historical Activity Theory and 'runaway objects'

In this book, we have drawn on third-generation activity theory, as conceptualised by Engeström (1987). We have juxtaposed two interdependent activity systems, the SLPs (in which the teachers participated) and the teachers' classrooms (where transfer should have taken place), to identify 'tensions' that influence the realisation of the 'object' in the activity systems. Tensions often lead to a 'contradiction of control', for example, teachers still presenting chalk-and-talk lessons, despite their positive experiences during the SLP. These tensions could stem from the 'community' (e.g. expectations of parents or principals), from 'rules' (e.g. the rigid pace-setters) or from any other node ('tools', 'subject', 'division of labour') in the activity system. The next phase in the project will use fourth-generation CHAT, which is currently being developed by researchers such as Engeström. To a great extent, fourth-generation CHAT has developed alongside the network society. Castells (2005) defines the network society as:

> [*A*] social structure based on networks operated by information and communication technologies based in microelectronics and digital computer networks that generate, process, and distribute information on the basis of the knowledge accumulated in the nodes of the networks. (p. 7)

These network societies influence the 'object' in the activity system. Engeström (2009) speaks of 'runaway objects'. These objects 'are poorly under anybody's control and have far-reaching, unexpected effects' (Engeström 2009:303–340). For such 'runaway objects' (e.g. teacher professional development in terms of the SLPs' goals), it is necessary to consider numerous activity systems that are affiliated with the object. This means that the object would comprise multiple perspectives and collaborations between various actors or stakeholders (Mentz & De Beer 2019b). Instead of having two juxtaposed activity systems (as explained in Ch. 3), many such activity systems are juxtaposed (the subject advisor within the context of the Department of Basic Education, the school principal within the school context, the parent at home, the teacher who has to navigate the tensioned space between the intended and the enacted curriculum, etc.). In Figure 1.3, each of the CHAT triangles represents a different activity system that influences the 'runaway object'.



Source: Engeström (2009:303–340).
FIGURE 1.3: Runaway object and activity systems.

Conclusion

The 11 chapters in this book, *The decolonisation of the curriculum project: The affordances of indigenous knowledge for self-directed learning*, provide a 'thick description' (Geertz 1973) of three years of research data collected on a DBR project. Despite the emerging themes that provide evidence of a successful intervention, there are still shortcomings that need to be addressed. This, I argue, can be achieved by using change laboratories that involve all stakeholders. Such an approach would also require the use of fourth-generation CHAT as a research lens.

This book provides scholars with an insight into the lived experiences of teachers and teacher educators involved in epistemological border-crossing between the Natural Science curriculum and IK. Third-generation CHAT provides an insight into the 'tensions' that developed between the intended curriculum (goals of the SLP) and the enacted curriculum, which unfolded in participating teachers' classrooms. This volume also raises pertinent questions that should be addressed in an era of the 'decolonisation of the curriculum'. In Chapter 3 to Chapter 6, reference is made to the rich South African ethnobotany. Germishuizen and Meyer (2003) estimate the number of angiosperm species in southern Africa to be 21 817. Van Wyk, Van Oudtshoorn and Gericke (2000) estimate that, of these plants, 3000 plants are regularly used as medicines by different cultural groups in the country. This brings the issue of ethics to the fore. How do we, as researchers, acknowledge the intellectual property rights of IK holders? What guidelines should underpin bioprospecting? These issues are interrogated in Chapter 11.

In a complex and continually changing 21st century, self-directed learning is critical in ensuring that the next generation develops the skills needed to achieve self-actualisation. It is, therefore, useful to go back in history and to focus on learning in traditional societies. De Beer and Mentz (Ch. 3) claim that the holders of IK are, by definition, self-directed learners, who had to solve authentic problems in their environments. The question should be asked whether or not this is a trademark of South African school education today. This focus on self-directed learning distinguishes this book from other publications on IKS.

Summary

This chapter provides an overview of how Chapter 2 to Chapter 11, although slightly eclectic in approach and focus, provide a 'thick description' (Geertz 1973) of how the inclusion of IK could lead to a better contextualisation of the STEM curriculum. In an era where the debate on the decolonisation of the curriculum is receiving increasing attention, research on the value of IK in the STEM classroom is important. This chapter also explores the affordances of IK for enhancing self-directed learning. A particular contribution of this chapter is that it locates the research conducted so far within a broader DBR project. It also looks critically at the shortcomings of current interventions, and how ‘change laboratories’ can address many of the shortcomings discussed in the book. Furthermore, this chapter focuses on the role of IK in the global village and how it can help solve perennial global problems.

Chapter 2

Different voices on decolonising of the curriculum

Lesley Le Grange
Department of Curriculum Studies, Faculty of Education,
Stellenbosch University, Stellenbosch, South Africa

Introduction

Decolonisation is not a new term. There was sporadic rebellion against colonial empires on the African continent in the 17th, 18th and 19th centuries. The term 'decolonisation' gained currency after World War II and signified the undoing of colonialism, often by means of the violent overthrow of colonial states. Decolonisation also refers to the undoing of intellectual colonisation, captured in the content and title of Ngũgĩ wa Thiong'o's (1986) seminal text, *Decolonisation of the Mind*.

In contemporary South Africa, there is a renewed interest in decolonisation that was spurred on by the student protests of

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2015 and 2016, most notably the #RhodesMustFall and #FeesMustFall campaigns. The #RhodesMustFall campaign involved students at the University of Cape Town (South Africa's oldest university) demanding the removal of the statue of British imperialist, Cecil John Rhodes, from its campus. For students (particularly black students), the Rhodes statue was a symbol of institutional racism and exclusion that they experienced at the university. The context of students' experiences was the lopsided demographics at the university – predominantly white academic staff and a growing black student community. According to Van Wyk (2014), even two decades after democracy, 73% of professors and associate professors in South Africa are white, which does not align with demographics of the South African population. In the #RhodesMustFall campaign, students re-invoked Wa Thiong'o's (1986:n.p.) expression, which was captured in one of the banners of some protesters, 'All Rhodes lead to the decolonisation of the mind'. The #RhodesMustFall campaign was closely followed by the #FeesMustFall campaign, which involved students at several universities in South Africa (mainly previously white universities) demanding free higher education in South Africa. The demand for free higher education was met by the South African government, and free higher education was introduced in 2018 for all first-year university students whose household income was below the threshold of R350 000 per annum (NSFAS 2018). However, the two campaigns were not delinked from one another and laid bare the lack of transformation at South African universities. Katlego Disemelo (2015), a PhD student from the University of Witwatersrand, writes the following about the two campaigns:

> It is, firstly, about access to equal and quality education. It is about teasing out the ever-so-confusing intricacies of class relations in post-apartheid South Africa. It is about eradicating the painful exclusion and daily micro aggressions which go-hand-in-hand with institutional racism within these spaces. And it is also about laying bare the failures of the heterosexual, patriarchal, neoliberal capitalist values which have become so characteristic of the country's universities. (n.p.)

One of the calls from the protesting students was for the decolonisation of the university and, more specifically, of the curriculum. In response to students' calls, Minister of Higher Education, Dr Blade Nzimande, called upon all universities to Africanise at a Higher Education Summit held in October 2015. Moreover, some universities appointed task teams (e.g. Stellenbosch University), while others appointed curriculum transformation committees (e.g. the University of Cape Town) to explore ways in which the curriculum of South African universities could be decolonised. We have also witnessed several conferences organised with the theme of decolonisation, special issues of journals with decolonisation as their theme and a burgeoning body of literature on the topic. This chapter, and this book, provides further evidence of the growing body of literature on the topic. In this chapter, I introduce various perspectives on decolonisation. The next eight chapters specifically focus on the affordances of IK in decolonising the curriculum. In Chapter 10, Speight Vaughn and Mdakane look at research ethics from the perspective of the marginalised (such as the Khoi-san). Le Grange (2019) avers that these developments signify a period of great ferment in South African higher education.

In this chapter, I discuss the different 'voices' on decolonisation of the curriculum in South Africa – voices of the past, different voices of the present, voices that are dominant and voices of that are silenced in the debate. But, firstly, a word on voice. Voice is variously used in academic writing and is the subject of much debate, particularly since the rise of semiotics and sign theory. Elbow (n.d.) distinguishes between the five senses of voice that could be identified in texts[1]:

1. audible voice (the sounds in texts)
2. dramatic voice (the character or implied author in a text)
3. recognisable or distinctive voice
4. voice with authority
5. resonant voice or presence.

1. Here, text refers to anything that carries meaning.

My usage of voice in this chapter does not relate to literal voice, or to the senses, but to the construct voice in academic writing. I use the term voice in a metaphorical sense to apply to the beliefs, views, perspectives and interests of people (and the more-than-human-world) and the opportunities that they have to express these. Before discussing different voices on decolonisation (of the curriculum), I firstly, discuss what is meant by decolonisation, followed by a discussion on what is meant by curriculum.

■ What is decolonisation?

As mentioned, decolonisation refers to the undoing of colonial governance when colonial countries attain independence. However, political decolonisation does not mean that all forms of colonisation are effaced. The first president of independent Ghana, Kwame Nkrumah (1965), coined the term neo-colonialism to indicate the continuation of ex-colonial influences after independence. Fanon (1967) also lamented at the end of the Algerian War that decolonisation had not occurred; instead, Africanisation was in place. Wa Thiong'o's call for the decolonisation of the mind after independence suggests that political decolonisation does not necessarily result in cognitive decolonisation.

A contemporary community of Latin American decolonial scholars provides us with a more nuanced understanding of what Nkrumah (1965), Fanon (1967) and Wa Thiong'o (1986) observed. They distinguish between colonisation and coloniality, and between decolonisation and decoloniality. The works of these scholars focus on the 'coloniality of knowledge' and the 'coloniality of being' (Mignolo 2007:156–157). They aver that although former European colonies attained independence, and in this sense we live in postcolonial times, the logic of coloniality remains with us. In other words, the systems of power that classify (othering), denigrate and subjugate remain prevalent, and, in a contemporary globalising world, are more insidious than previous, more naked, forms of colonisation. Drawing on the insights from Quijano, Mignolo (2007:156) describes the colonial matrix of power as having four interlocking domains, namely, control of economy (land appropriation, exploitation of labour, control of natural resources), control of authority (institution, army), control of gender and sexuality (family, education), and control of subjectivity and knowledge (epistemology, education and identity formation).

Decoloniality, therefore, concerns a critical awareness of the logic of coloniality (the colonial matrix of power); it is a critique of coloniality, resists expressions of coloniality and takes actions to overcome coloniality. Applied to South Africa, the coloniality or decoloniality lens enables one to understand that apartheid was a particular manifestation of coloniality rather than a period distinct from colonialism, as Jansen (2017) suggests.

Decolonisation is not always used to refer to the removal of colonial systems of governance. It is also invoked by indigenous scholars or communities to represent a broader process whereby colonised peoples correct the deficient ways in which they have come to be defined, seek self-determination, discover and recover their IK and sense of self, mourn the pain inflicted upon them by colonisation, etc. Chilisa (2012:15–17, cited in Le Grange 2016a:4–5) suggests five phases in the process of decolonisation:

1. rediscovery and recovery
2. mourning
3. dreaming
4. commitment
5. action.

Rediscovery and recovery is the process whereby colonised peoples rediscover and recover their own history, culture, language and identity. *Mourning* refers to the process of grieving the sustained onslaught on the world's colonised peoples' identities and social realities. It is an important part of healing and leads to dreaming. *Dreaming* is when colonised peoples invoke their histories, worldviews and IKS to theorise and imagine alternative possibilities such as a decolonised curriculum.

Commitment relates to academics or students pledging to labour vigorously to include the voices of colonised peoples in the university curriculum. *Action* is the phase where dreams and commitments are translated into concrete plans for social transformation. Smith (1999) identified the following elements of decolonisation:

- deconstruction and reconstruction
- self-determination and social justice
- ethics
- language
- internationalisation of indigenous experiences
- history
- critique.

Deconstruction and reconstruction concerns correcting what has been wrongfully written about indigenous peoples and laying bare how their life experiences have become distorted and the deficit ways in which they have become labelled (Chilisa 2012). *Self-determination and social justice* is about seeking legitimacy for the knowledges, histories, experiences and ontologies of indigenous peoples. *Ethics* is concerned with putting in place regulation that will ensure the protection of IKS. *Language* concerns the importance of adopting indigenous languages for teaching and learning as part of the anticolonial struggle. *Internationalisation* of indigenous experiences relates to indigenous scholars sharing common experiences, issues and struggles in the spaces that globalisation affords. *History*, in this context, involves a study of the past to recover the history, culture and languages of colonised people and to bring them to bear on the present. *Critique* concerns a critical assessment of the imperial model of the academy that does not offer opportunities for indigenous scholars to communicate from their own frames of reference (Chilisa 2012).

A question that is often asked is, what are the links between decolonisation and the constructs of Africanisation and indigenisation? In my earlier reference to Fanon, it is evident that, for him, there is a difference between decolonisation and Africanisation. For Fanon, Africanisation means merely replacing colonialists with Africans without fundamentally changing the structures of governance and the values of society. Africanisation, in the sense that Fanon used it, was tantamount to Nkrumah's concept of neo-colonialism. Prah's (2004) distinction between Africanisation and Africanism is helpful. For Prah (2004), Africanisation relates to the deliberate deployment of Africans in positions of importance so that African majorities are demographically represented in all areas of social life. Although this may serve as the basis for Africanism, the latter is concerned with making African culture the centre of Africa's development or, as Prah (2004:105) succinctly puts it, 'African culture should occupy a central position in the overall social activity of Africans'. For Fanon, decolonisation on the African continent would require both Africanisation and Africanism. There is one other obvious distinction between Africanisation and decolonisation – Africanisation is necessarily circumscribed to Africa and African diaspora, whereas decolonisation is a construct that has broader meaning and application across the globe. Decolonisation has been embraced by indigenous peoples globally, as captured in my discussion of the process of decolonisation that Chilisa (2012) identifies, and in the elements of decolonisation that Smith (1999) identifies. Decolonisation is evidently a broader concept than indigenisation, but the latter could be viewed as one form of decolonisation. For a more detailed discussion of the resonances and dissonances between decolonisation, Africanisation and indigenisation, see Le Grange (2018). This brings us to a discussion on curriculum.

■ Curriculum and its decolonisation

Curriculum is a polysemous term. Its meaning differs based on context, historical times and philosophical assumptions. Generally, curriculum relates to what knowledge is included in teaching and learning programmes, as captured in Herbert Spencer's (1884) perennial question in the title of his book, *What knowledge is of most worth*? What knowledge, and whose knowledge is of most worth, is at the heart of what the decolonising of the curriculum is all about. However, I shall broaden the discussion so that the concept curriculum is expanded to a construct that involves more than 'what knowledge' is included in education programmes.

Although there are different perspectives on curriculum, one view of curriculum became dominant in the latter half of the 20th century and continues to do so in the first two decades of the 21st century. This view of curriculum is neo-Tylerian[2] and is described by Gough (2013:1216, as cited in Le Grange 2016a) as follows:

> Tyler and Biggs represent curriculum as a simple, tightly coupled system in which it is both possible and desirable to closely align what students do in order to learn with intended learning outcomes and how they are assessed. (p. 7)

This instrumentalist and utilitarian view of curriculum is colonising in the sense that it proposes one way of knowing, being and becoming as *the only* way of knowing, being and becoming. In other words, this dominant view of curriculum does not take into consideration the uniqueness of each individual; each person's peculiar desires, hopes and beliefs; as well as significations of race, gender, sexual orientation, etc. However, Le Grange (2016a) opens up ways of thinking about curriculum in order to invigorate potentially decolonising lines that escape the colonising effects of curriculum produced in the Tylerian mould. I revisited Le Grange's (2016a) ideas on curriculum to show how he engages with the works of scholars such as Madeleine Grumet (1981), Ted Aoki (1999), Elliot Eisner (1985), Pinar (1975, 2011) and Jason Wallin (2010).

Madeleine Grumet (1981) provides an alternative view of curriculum to that of Tyler (1949) and describes 'curriculum as the stories that we tell students about their past, present and future' (Le Grange 2016a:7). Given that we have not yet been

2. Tylerian refers to the American scholar Ralph Tyler who argued that curriculum development involves responding to the following four questions: 'What educational purposes should the school seek to attain?', 'What educational experiences can be provided that are likely to attain these purposes?', 'How can these educational experiences be effectively organized?' and 'How can we determine whether these purposes are being attained?' (Tyler 1949:1).

liberated from the fetters of Tyler's notion of curriculum in the 21st century, Grumet's (1981:n.p.) alternative view of curriculum is pertinent because it enables us to ask critical questions, such as 'which stories are students told about their past, present and future?', 'whose stories are they'? and 'who tells the stories?' Another scholar, Ted Aoki (1999, as cited in Le Grange 2016a:7) argues that curriculum should not only focus on the planned (the *curriculum-as-plan*) but also on how it is lived (the *curriculum-as-lived*) – how the curriculum is lived by students and lecturers.

Aoki importantly points out that legitimating the *curriculum-as-lived* does not discard the *curriculum-as-plan*, but legitimating the former produces a tensioned space in between the two, which is a space of struggle, creativity and transformation. What the student protests of 2015 and 2016 laid bare was that the lived experiences of students (both inside and outside of the university) had not been recognised by many lecturers and university managers, and that this dimension of curriculum did not enjoy legitimacy in the university. Attentiveness to Aoki's wisdom of legitimating the *curriculum-as-lived* (alongside the *curriculum-as-plan*) could have potentially transformative effects in South African universities. Moreover, the tensioned space between the *curriculum-as-plan* and the *curriculum-as-lived* has the potential to become a decolonising space.

Curriculum scholars such as Eisner (1985, as cited in Le Grange 2016a:8) have also distinguished between three broad perspectives on curriculum that have not received much attention with respect to universities, namely, the *explicit, implicit* (hidden) and *null* curriculum. The *explicit* curriculum is what students are provided with by lecturers, such as module frameworks, prescribed readings, assessment guidelines, etc. The *implicit* (hidden) curriculum is what students learn about the dominant culture of a university and what values it reproduces. What PhD student Katlego Disemelo (2015) expresses, in the quote used earlier, bears testimony to her insights into the hidden curriculum of South African universities – the 'neoliberal capitalist values', 'institutional racism', 'patriarchy', etc.

The hidden curriculum relates to what the molar identity of a university is – the 'ideal' against which everyone is measured and declared different. 'The *null* curriculum is what universities leave out – what is not taught and learned in a university' (Le Grange 2016a:8). An example would be the fact that IK is not taught in many universities, or faculties of universities. The distinction between the three curriculum types helps to ask, for example, what the hidden curriculum of Stellenbosch University is, or what the null curriculum of NWU is.

William Pinar (1975, as cited in Le Grange 2016a:8) first invoked the etymological root of curriculum, the Latin term *currere*, which means 'to run the course'. He did so to refocus curriculum on the significance of individual experience; 'whatever the course content or alignment with society or the economy' (Pinar 2011:xii). *Currere* foregrounds the individual and, Pinar (2011:2) argues, is a complicated concept because each of us is different – in our genetic makeup, our upbringings, our families, and more broadly our race, gender, class, etc. Put simply, *currere* shifts the attention away from the concept of a predetermined course to run and focuses on how the course is run by each individual, given each person's unique makeup, context, hopes, aspirations and interactions with other human beings and the more-than-human world. In other words, each individual has his or her own life story, and understanding one's own story through academic study is at the heart of curriculum. Pinar develops *currere* as an autobiographical method with four steps or moments – *regressive*, *progressive*, *analytical* and *synthetical* – that depict both temporal and reflective moments for autobiographical research of educational experience (Pinar et al. 1995):

- The *regressive step* focuses on the past, a moment in which one re-enters the past so as to enlarge and/or transform one's memory.
- The *progressive moment* or *step* focuses on the future. Pinar (2004:36) avers that in this step, one looks forward to what is not yet present; one meditatively imagines possible futures and also how the future inhabits the present.

- The *analytical step* involves a distancing from one's past and future to create a space of freedom in which one analyses how the future is present in the past, the past in the future and the present in both (Pinar 2004:36–37).
- The *synthetical step* brings about a sense of wholeness as one re-enters the lived present and asks 'what the meaning of this present is?' It also involves a process of awareness of what flows within us, what drives us to do and be, and what gives meaning to our lives.

Pinar's autobiographical method, *currere,* resonates with the project of decolonisation in that a fundamental concern for both is the (re)construction of the subject. Pinar (2011) argues that subjective reconstruction, a central concern of *currere*, is one form of decolonisation. Decolonial revolutionary Fanon (1967) emphasises the primacy of the liberation of the individual in the process of decolonisation. Goldie (1999:79) goes so far as to say that for Fanon, 'true liberation is the achievement of subjectivity'. Pinar (2011) neatly captures the role of *currere* in the psychosocial transformation of the colonised subject:

> Autobiography – the regressive-progressive-analytic-synthetic method of *currere* – can be political when it disables, through remembrance and reconstruction, colonisation through interpellation. By affirming the capacity to restructure one's subjectivity, autobiography disentangles us from absorption into collectives – even when presumably these are self-affirming cultural identities. (p. 40)

Importantly, however, Pinar (2011) does point to the danger of the narcissism of identity politics and therefore advocates invoking *currere* to perform a collective autobiography as an impetus for political mobilisation. The regressive step of *currere* enables the individual to re-enter the past and to focus on colonial influences on his or her life and, in particular, how the individual has actively taken up colonial discourses. This step is also a moment in self-criticism and marks the beginning of the individual's efforts to rid himself or herself of the fetters of colonial thought. The progressive step focuses on the future and the individual imagines a future that is more just and more democratic, for example. In the analytic step, the individual distances himself or herself (akin to bracketing in phenomenology) from the past and future and analyses how the past, future and the present are imbricated in one another. By distancing himself or herself from the past and the future, the individual is able to experience a moment of freedom from the present – free from colonising thoughts. In the synthetic moment, the individual re-enters the present with a renewed sense of self, able to see the wholeness of past, present and future, and asks, 'what does this mean and what can I do?' This is the moment when the individual is able to join others in order to mobilise them into collective action to alter the present, and this will make possible a different future.

As cited in Le Grange (2016a:10–11), recently, a Canadian scholar, Jason Wallin, revisited the notion of *currere*. Inspired by Deleuze and Guattari (1994), he reframed the idea of a concept, proposing that it is not a name attached to something, but a way of approaching the world. Deleuze and Guattari's (1994) interest is not in what a concept is, but in what it does. Wallin draws attention to the paradoxical character of *currere*'s etymology: its active and reactive forces. Thinking of curriculum as an active conceptual force means that the concept does not convey an *a priori* image of a pedagogical life. It instead relates to the immanent potential of the becoming of a pedagogical life – the multiple coursings of a pedagogical life that exists prior to thought. As Wallin (2010) neatly captures:

> [*To*] *run* implies that the conceptual power of *currere* is intimate to its productive capacity to create flows, offshoots, and multiplicitous movements. For example, the 'running' roots of rhizomatic bulbs and tubers extend to create new interfaces with other organic and nonorganic bodies, extending the experience of what a body can become .... Running flows of volcanic magma create new courses along and through the ostensible stability of the Earth's mantle, articulating the immanent geomorphic potential of territories to deterritorialisation [...] A musical 'run' creates lines of flight potentially incongruous with the codes that structure it, overflowing, extending, and traversing tonal registers in producing new affects. (p. 2)

The conceptual power of *currere* implies newness, creation of things unforeseen, experimentation, expanding of difference and movement. This notion of curriculum makes possible multiple pathways for the becoming of pedagogical lives and therefore is decolonising. *Currere's* reactive form colonises, where one way of knowing becomes *the only* way of knowing. The reactive power of *currere* severs *currere* of its immanent potential to become other.

I have presented different ways of understanding curriculum so as to invigorate decolonising vectors that might enable us to live, be and become other (different). I now discuss different voices involved in South Africa's current (cognitive) decolonial moment.

Different voices on decolonisation

In South Africa's decolonial conversation currently taking place, a range of voices are emerging. I shall discuss some of the voices in South Africa's decolonial moment, most notably voices of the past, voices of university leaders, voices of students and voices silenced. Many more voices could have been discussed in this chapter, but such an effort would have required a lengthier treatise. Attempts to make sense of moments, such as South Africa's present decolonial moment, almost inevitably involve invoking voices of the past — those who have passed on and/or those who are still with us in body, but whose works might be gathering dust. In the burgeoning literature on decolonisation of the curriculum, we see or hear the voices of, among others, Steve Biko, Aimé Cesaire, Emmanuel Eze, Frantz Fanon, Kwame Nkrumah, Albert Memmi and Ngũgĩ wa Thiong'o. The lives and works of these people are invoked to help us in our struggle to make sense of the present, to find points of resonance and dissonance between their views and ours, to rethink their ideas so as to create something new in the present, and to enable us to imagine a different future that is a synthesis of the past and the present (but more than the sum of the two). But, let me share a few examples of how the thoughts and ideas of some of these authors are being (re)invoked in the present. Steve Biko is being (re)invoked in arguments to advance black studies in South Africa (and elsewhere) based on the idea that blackness is an important and productive counter-narrative in a context where whiteness dominates (Lamola 2018). Fanon's life and works help us to make sense of the difference between decolonisation and Africanisation. They give us a sense of the importance of the individual labour that both the colonised and the coloniser need to undergo in the process of psychosocial transformation – Fanon's assertion that there can be no decolonisation without individual liberation is noteworthy. This insight of Fanon has enabled us to generate lines of connection with Pinar's *currere* (discussed earlier), opening up ways of understanding decolonisation as an inherently curriculum matter.

Eze's (2011) idea of a postracial future enables us to critically examine the issue of 'race' in current discourses on decolonisation in South Africa. I shall return to the issue of race later. The (re)invocation of Wa Thiong'o's 'decolonisation of the mind' by both students and scholars invites critical questions about the productiveness of such a move. The focus on the mind neglects the body and spirit and reinscribes Descartes' (1637) problematic *cogito*, 'I think therefore I am', which has resulted in the privileging of the mind in modern education, while the body is declared inferior – the destruction of the more-than-human-world or other-than-human world ('nature') by humans because of their 'superior' minds.

We have also heard the voices of university leaders in the media during the student protests. In his book, *As by Fire,* Jansen (2017) interviews 11 South African university vice-chancellors concerning their lived experiences of the student protests of 2015 and 2016. Jansen's (2017) book gives us an insight into the views and experiences of selected vice-chancellors and, of course, his own voice (both as Vice-Chancellor and the author of the text). In the book, vice-chancellors share their shock at the level of violence during the protests, the fact that the government had not listened to their warnings about declining subsidies and rising student fees, challenges to their leadership that they experienced and so on. Throughout the book, there are lengthy quotes from the vice-chancellors, but, interestingly, Jansen does not ask the vice-chancellors about their views on decolonisation (of the curriculum). He chooses to author a chapter in the book on decolonisation without any quotations from the other vice-chancellors. However, in one of the other chapters, a Vice-Chancellor raises an issue that is a recurring theme in the decolonisation conversation in South Africa, that is, the issue of 'race'. I quote Rhodes University Vice-Chancellor, Sizwe Mabizela (in Jansen 2017):

> One dimension that has troubled me immensely about the recent student activity is the essentialisation of race and the view that by virtue of the pigmentation of your skin, you are white. You therefore can't say anything about black people and the experience of black people. You must be silent, keep quiet. You know nothing about it. And I think this is so antithetical to what it means to be a university.
>
> One of our outstanding professors, who happens to be a white woman, an excellent academic, has been so frustrated because in political science, three black students were simply saying to her, 'Shut up! You don't know what it means to be black'. The same thing happened to another of our white academics, a South African, who wrote a book on Ubuntu, and he was taken to task: 'What do you know about Ubuntu?' (p. 131)

I shall return to the issue of 'race'. But, I first proceed to briefly discuss some aspects of Jansen's chapter on decolonisation. In his chapter, Jansen claims to debunk the sense and non-sense in relation to the decolonisation of the curriculum. He provides a background to the topic 'decolonisation' and attempts to clarify what is meant by the 'decolonisation of curriculum'. In the latter half of his chapter, he raises three arguments about decolonisation of the curriculum that warrant further discussion.

Jansen (2017) points out that the rhetorical value of calls to decolonise the curriculum in student politics is far removed from the desire to change the curriculum in universities. Moreover, students appear to invoke notions of decolonisation for symbolic reasons only, as these students and academics return to the settled curriculum after the protests. Consequently, no meaningful change takes place. He points out that history shows this to be the case and uses the example of the People's Education movement of the 1980s.

Jansen's invocation of political symbolism is insightful, but there might be other reasons as to why meaningful curriculum change has not happened in universities following student protests. Typically, students do not inhabit universities for extended periods of time; they complete their studies and move on. Students' calls during protests can, therefore, only serve as a trigger or catalyst for curriculum change. Curriculum change depends on what academics and university leaders do, which requires a commitment to complete the ethico-onto-epistemological[3] labour. It is worth noting that the student protests in Paris in 1968 provided the stimulus for what, today, is called French poststructuralism, a movement and academic discipline that has radically changed thinking in both the global north and global south; its protagonists (such as Michel Foucault) remain the most cited scholars, even after their deaths. A second argument Jansen makes is that most academics are disciplinarians in the sense that they have been socialised into particular disciplines and, therefore, engaging with other knowledges would be challenging. Jansen is correct, but we also know that disciplinary knowledge is proving to be inadequate in addressing pressing challenges of our time, such as growing inequality in the world and unprecedented levels of environmental problems. The fact that one is a disciplinarian does not mean that one's professional identity cannot change – professional identity is not fixed but is fluid. We are already witnessing the de-territorialisation of disciplinary knowledge and the emergence of interdisciplinary, multidisciplinary and transdisciplinary trajectories. Le Grange (2017) avers that the emergence of transdisciplinary research could be understood as the consequence of at least three separate but related developments:

- the fissures internal to disciplines
- the emergence of a socially distributed knowledge system brought about by the massification of higher education
- the limits of disciplinary knowledge to respond to the complexity of planetary problems.

3. I aver that ontology, axiology and epistemology are not separate categories, but are imbricated in one another.

A third argument put forward by Jansen (2017:167) is an issue I referred to earlier. Jansen argues that what was evident in the students' protests was a popular understanding of decolonisation that he describes as the 'hard version' of Africanisation – 'a dangerous nativism often expressed in racist terms'. He writes, '[i]t is unapologetically the black African, to the exclusion of all other South Africans' (Jansen 2017:167). Jansen's position resonates with the words of the Vice-Chancellor of Rhodes University quoted earlier and to Eze's (2014) view that a specific focus on the condition of black people is 'to indulge in a parochial social anthropology, racial essentialism and jingoistic race-based provincialism' (Lamola 2018:2). However, an interest in the specific condition of black people is not tantamount to engaging in biological or racial essentialism.

I, of course, agree that there is no simple association between the colour of a person's skin and his or her manner of thinking or being. However, in South Africa (and elsewhere), there are privileges derived from being white, and white lived experience has become idealised (whiteness) in the modern world. Moreover, Lamola (2018:2) argues that 'whitely thinking' has become the mainstream epistemology of the modern world, which has resulted in the subjugation of black being and lived experience. This, as I have argued, is what the student protests of 2015 and 2016 laid bare in relation to South African universities.

In his discussion on blackhood and the self, Lamola (2018:7) argues that black existence needs to be understood in terms of what he calls 'existentiality' and not essentialism. By existentiality, he refers to the intra-subjective consciousness of the black person, and the external institutional impositions on the black person's self-consciousness. He (Lamola 2018) writes:

> The given fact of existence as a black person, as a conscious being, is therefore about self-understanding (and self-negotiation) as a black person in constant confrontation with externally imposed definitions and categorisations of black personhood. It is in this sense that this self-negotiated selfhood is blackhood. (p. 7)

Lamola's (2018) blackhood resonates strongly with Pinar's method of *currere*, and the latter could contribute systematicity to the labour of the black person (student) in the process of engaging in Lamolo's self-understanding and self-negotiation – blackhood becomes curriculum.

During the student protests, we heard the voices of students – we heard their cries and calls, such as 'decolonise the curriculum'. Some students expressed their ideas articulately, such as Disemelo quoted earlier. Other expressions were problematic, such as those from some students at the University of Cape Town who demonstrated a lack of understanding of Western science in the #ScienceMustFall campaign (see Jansen 2017:155).[4] Nevertheless, I wish to highlight a particular moment of the #FeesMustFall campaign that is worth reflecting on.

There were many attempts by police armed with guns to silence the voices of students. In one moment during the protests, three female students exposed their naked breasts as they faced police armed with guns. Images of the three half-naked students went viral, and many commented. But, journalist Gillian Schutte captures the moment so poignantly, demonstrating the importance of the body (that the body has a voice), and gives literal meaning to Deleuze's figuration, 'we cannot know what a body will do'. Schutte (2016) writes:

> They looked brave and vulnerable. Their naked stomachs and breasts juxtaposed with police in riot gear armed with guns had a profound effect on all. The stark contrast was shocking and rendered the violence of men with guns and riot gear hyper-visible. Naked flesh exposed on the site of violence makes a visceral anti-war statement and this was war. It was a war declared by state and institution against the black child who dared to rise for their rights. Many dismiss the women's naked protest. They bemoaned the fact that yet again black women were forced to lose their dignity by stripping naked. But nakedness is not a loss of dignity when voluntarily used in protest. It is resistance against those who would strip them of their dignity. Women's breasts are a powerful semiotic of resistance. Breasts are the most vulnerable part of their bodies. They are also

4. This of course does not mean that Western science should not be decolonised. But decolonisation does not mean destruction (see Le Grange 2016).

> a source of nurturing. Even men with guns have been nourished on their mother's breasts. Breasts are both robust and vulnerable. These three half-naked women disarmed the police with their naked cries. The police did not fire their guns again. (n.p.)

I contend that the protest movements of 2015 and 2016 could have potentially transformative effects on higher education in South Africa. The conferences, burgeoning literature, etc. present evidence of some notable effects. However, meaningful curriculum change will depend on finding ways to listen to the voices of students in a sustained way – that their lived experiences and perspectives are taken seriously by all role players in higher education – as their voices are a barometer of broader challenges faced by society. However, meaningful curriculum change will require a radical rethinking of higher education, a discussion I return to in my parting thoughts.

There are also voices that have been silenced in decolonisation conversations, and I am not referring to human voices, but the voice or voices of the more-than-human world. It is the voice or voices that indigenous peoples know and have come to understand. Indigenous people, for example, know the importance of listening to the voice of the land – that the land is their teacher and not something that is to be possessed and exploited for economic gain. More recently, some Western scholars have come to appreciate the agential capacities of the more-than-human world, conceiving of a new materialism. New materialism questions the privileging of subjectivity and representation and, according to Braidotti (2012:171), replaces textual and other deconstruction with the ontology of modulated presence. New materialists find inspiration from the thinking of the late Deleuze, who collaborated with Guattari, in placing the human on an immanent plane, thereby stripping it of its ontological privilege. Moreover, new materialists hold that all matter (including organic matter) has agential capacities. This idea is depicted in Barad's (2007:132) concept of 'agential realism'. About the idea that 'nature' is agentic, Gough (2016:52) writes, '[...] it acts, and those actions have consequences for both the human and nonhuman world'. Crucial here is that, even though the more-than-human-world ('nature') is silenced in discourses on decolonisation (of the curriculum), 'nature' will not be silenced and its voice is thunderous – it hits back hard and its effects are real, as we are already witnessing with climate change.

Conclusion

Some parting thoughts – Rethinking curriculum through improvisation

As cited in Le Grange (2016b:32), in 1981, Japanese-Canadian curriculum scholar Ted Aoki learnt that Bobby Shew (a jazz trumpeter) was a visiting scholar to the music department at the University of Alberta. Aoki loved music and used the opportunity to invite Bobby Shew to speak at a staff and student seminar in his department. Aoki asked Bobby Shew to speak to, sing to or play to 'when does an instrument cease to be an instrument?' and 'what is improvisation?'. Why did Aoki ask Shew to address these two questions? For Aoki (in Pinar & Irwin 2004:368), the field of curriculum had become fraught with performative words reflective of instrumentalism (words such as goals and objectives and products, achievement and assessment); education was under the technological rationality – '*a* way to do, has become *the* way of doing [...]'.

To the first question, Shew replied (Pinar & Irwin 2004):

> When music to be lived calls for transformation of instrument and music into that which is bodily lived – The trumpet, music, and body must become as one in a living wholeness. (p. 368)

To the question on what it is to improvise, Shew retorted that, when improvising with fellow musicians, they do not only respond to each other but also to whatever calls upon them in that situational moment, and that no two situational moments (like life itself) are the same (Pinar & Irwin 2004).

Aoki (in Pinar & Irwin 2004:369) invites us to rethink the instrumental language in curriculum talk, captured in expressions such as ‘curriculum development’, ‘curriculum implementation’, ‘curriculum integration’ and ‘curriculum piloting’. He suggests that we should instead develop a new language that is non-instrumental, with expressions such as ‘curriculum improvisation’ and, I would add, ‘curriculum experimentation’. Expressions such as ‘curriculum implementation’ require lecturers to be loyal to a curriculum and be indifferent to their lives, the lives of students and the context in which they find themselves. In contrast, when lecturers are improvisers, they are attuned to both their own and students’ changing lives as well as to the mutuality of the contexts in which they find themselves. Le Grange (2014:1292, and cited in 2016b:32) argues that in the case of curriculum implementation, the performance of the lecturer mimics the conductor of a classical orchestra where the composer is often positioned external to the performance. Although there is some interpretation of the musical piece, the conductor (lecturer) has to ensure that the members of the orchestra (learners) play each note correctly. A deviation from the musical sheet (the intended curriculum) is viewed as a mistake (Le Grange 2014). However, in the case of curriculum improvisation, pedagogy is akin to improvisational jazz where every musician (student) is a composer. In the classroom context, although the (lecturer) may be more experienced and ‘knowledgeable’, the educative performance, as in the case with improvisational jazz, is an assemblage of interactions that make both lecturer and student imperceptible (Le Grange 2014:1292, cited in Le Grange 2016b:33).

Performative words, such as aims and objectives, outcomes, curriculum development, curriculum implementation, constructive alignment, sequencing and pacing, are part of instrumentalist language. The effects of instrumental rationality are particularly dangerous because they are colonising, homogenising, dehumanising, domesticating, etc. (for detail, see Le Grange 2014, 2016a; cited in 2016b:33). Curriculum becomes moribund and pedagogy banal. Pedagogy becomes cold and heartless, and the Earth becomes a stage on which pedagogy is performed. Furthermore, multiple pathways (that exist prior to human thought) for transforming the world, and for creating alternative futures, are reduced to a single way of knowing, being and becoming.

Bobby Shew's (in Pinar & Irwin 2004:n.p.) reply to Aoki's question, 'when does an instrument cease to be an instrument?', is worth returning to. I specifically refer to Shew's response, 'the trumpet, music, and body must become as one in a living wholeness' (in Pinar & Irwin 2004:n.p.). In other words, trumpet, music, and body become imperceptible. However, I wish to extend Shew's insight beyond the human and the instruments or artefacts he or she produces to a post-anthropocentric idea that includes oneness with the Earth. By doing so, the subject of education (that is, post-anthropocentric) is not an atomised individual but is ecological, embedded in and embodied by the material flows of the Earth or cosmos, constitutive of these flows, making the subject imperceptible. According to Le Grange (2012), this idea is captured in the Shona construct, *ukama*, which means relatedness of everything in the cosmos. Aoki's notion of improvisation could also be expanded not only to be concerned with the human that reverberates from within and is animated but also to include the vibrations of the Earth, its flows, rhythms and creative intensities.

Aoki (in Pinar & Irwin 2004:373, cited in Le Grange 2016b:34) argues that the instrumental language in curriculum privileges the visual (*videre*) because this approach to curriculum is based on the Natural Sciences, where observation is privileged. Aoki argues for the importance of hearing or listening (*sonare*), that we need to hear the words of the instrumental language, which dominates discourses on schooling so that these performative words and the instrumental language in which they are couched can be transcended. Transcending instrumental language is the starting point for a decolonised curriculum. Moreover, Aoki suggests 'what' we might listen to by quoting Heidegger, 'we have ears because we are hearkening, and by way of this heedfulness, we are allowed to listen to the Song of the Earth' (in Pinar & Irwin 2004:375). I wish to add that we also need to feel (*sentire*) the Earth – the effects of its material flows and its creative intensities.

Summary

There is a renewed interest in decolonisation in South Africa in the wake of the student protests of 2015 and 2016. Following the protests we witnessed, review committees were established at universities to investigate ways in which the curriculum could be decolonised. We also witnessed several conferences organised with the theme of decolonisation, special issues of journals with decolonisation as the theme and a burgeoning body of literature on the topic. In this chapter, I clarify what is meant by the concepts of decolonisation and curriculum. I discuss the different voices on decolonisation of the curriculum in South Africa, including voices of the past, different voices of the present, voices that are dominant and voices that are silenced in the debate. I conclude that decolonising the curriculum requires a radical rethinking of the concept of curriculum, so that it is liberated from instrumentalist or performative language by introducing a language of improvisation.

Acknowledgements

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- Le Grange, L., 2016a, 'Decolonisation of the university curriculum', *South African Journal of Higher Education* 30(2), 1–12, from https://doi.org/10.20853/30-2-709.
- Le Grange, L., 2016b, 'Think piece: Sustainability education and (curriculum) improvisation', *South African Journal of Environmental Education* 32, 26–36.

Chapter 3

The use of Cultural-Historical Activity Theory in researching the affordances of indigenous knowledge for self-directed learning

Elsa Mentz
Research Unit Self-Directed Learning,
Faculty of Education, North-West University,
Potchefstroom, South Africa

Josef de Beer
Research Unit Self-Directed Learning,
Faculty of Education, North-West University,
Potchefstroom, South Africa

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Introduction: Can the phoenix rise from the ashes?

As an emerging economy, South Africa needs to be internationally competitive; this dictates that the country should produce innovative scientists and engineers. Good Mathematics and Science teaching and learning are a *sine qua non* for global competitiveness. Unfortunately, South Africa performs dismally in international benchmark tests, such as the TIMSS (Alex & Juan 2016; De Beer 2016). There are many reasons for this poor performance of learners in Science and Mathematics. Two of the reasons are the quality of teachers and the problems with the curriculum (Bernstein 2011; De Beer 2016).

Researchers such as De Beer and Petersen (2016) indicate that the school science curriculum is often not relevant to the local context. Consequently, learners are not inspired by the curriculum themes. In addition, many classrooms today are characterised by transmission-mode (chalk-and-talk) approaches, and this often nurtures reproductive behaviour and shallow learning. In many classrooms, learners are primarily prepared for summative tests and examinations, which favour the memorisation of facts. In the process, the acquisition of 21st-century skills such as communication, critical thinking, creativity and collaboration is marginalised.

For the phoenix to rise from the ashes, firstly, we have to promote Self-directed Learning (SDL) among both teachers and learners. Secondly, we have to assist teachers in their professional development to enable them to better contextualise curriculum themes for learners by, among others, facilitating an epistemological border-crossing between IK and the science curriculum.

In this chapter, the authors focus on a SLP for teachers, in which IK is used as a vehicle to promote SDL. This context serves to illustrate the utility value of CHAT as a research lens. A CHAT lens was used to look at research data collected in two provinces in South Africa, namely, Limpopo and the Northern Cape province.

The context of this research: Scaffolding teachers' learning and professional development to enhance self-directed learning

There are a number of perennial problems that plague teacher professional development in South Africa. As mentioned above, school education in South Africa is often characterised by transmission-mode teaching and learning. The key to addressing this is teacher professional development (McKinsey Report 2007). This report clearly states that 'the main driver of the variation in student learning at school is the quality of the teachers' (McKinsey Report 2007:15). Osamwonyi (2016:84) provides a compelling argument for the importance of the professional development of teachers. Two of the reasons given for the importance of in-service teacher education are:

- According to Kpangham (1992) and Osamwonyi (2016), teachers are members of an under-educated profession. Furthermore, the conditions under which teachers work do not promote the type of peer interaction, or the establishment of communities of practice, that could support individual teachers in their professional development in order to improve their performance.
- There is a growing expectation 'that teachers should reform their own practices, as this is the only way in which meaningful curriculum development could take place in the daily routine of classrooms' (Osamwonyi 2016:84).

Bernstein (2011:22–23) refers to Rollnick and Brodie's (2011) principles for effective professional development programmes that could overcome the inherent problems in many in-service training programmes. These include the following:

- Workshop-type disjointed professional development, which is dominant in South Africa, is not effective.
- A focus on a number of instructional priorities over a long period of time is most effective.
- Teachers learn best within communities of practice, with the support of 'critical friends'.

- Quality professional development programmes immerse teacher participants in enquiry and PBL.

De Beer and Kriek (n.d.) add three additional criteria for successful teacher professional development programmes, namely:

- Quality teacher professional development programmes should be underpinned by a sound theoretical framework.
- Self-directed learning should be promoted during professional development.
- Other partners and stakeholders need to join hands with teacher education institutions in facilitating effective teacher professional development.

Guided by these principles, NWU developed a SLP for science teachers to scaffold their learning and enable them to facilitate epistemological border-crossing between IK and science, because as Vygotskyan scholars we believe that learning leads to development.

This SLP was underpinned by a social-constructivist theoretical framework, namely, scaffolding teacher learning across the 'zone of proximal teacher development' (ZPTD) (Warford 2011). Warford applied Vygotsky's (1986) well-known construct of the 'zone of proximal development' (ZPD) to teacher education. He then showed how teachers' learning could be scaffolded across the ZPTD – from their actual to their potential development through four stages. These four stages, shown in Table 3.1, were used during the conceptualisation of this SLP. The stages are self-assistance, expert-other assistance, internalisation and recursion (Warford 2011:254).

The scaffolding of teachers' learning during the SLP was focussed on the enhancement of their SDL in order for them to implement what they had learnt, to apply the new knowledge and skills in different situations, and to think creatively about new active learning strategies for their classes. They should have been equipped with skills to be lifelong learners – willing to learn more, experiment with new teaching strategies and constantly develop new ideas to motivate learners.

TABLE 3.1: Scaffolding teachers' learning across the ZPTD during the SLPs.

ZPTD Stage	How this was addressed during the SLP
Self-assistance	It was deemed crucial first to establish what knowledge and preconceived ideas teachers held, for example, by completing a questionnaire and group discussion. This stage provided an opportunity for teachers to identify personal problems experienced in their teaching and to set their own learning goals accordingly. It also provided the teacher educator with insights into the beliefs and practices that teachers brought with them into the professional development programme.
Expert-other assistance	During the SLP, teachers' learning was scaffolded through PBL and CL methods, as strategies to achieve their learning goals. For instance, teachers engaged in laboratory techniques to test the antimicrobial activity of medicinal plants. Apart from facilitator assistance, peer mentoring also occurred. The focus was on 'field-based demonstrations of how innovative teaching practices are carried out in actual classrooms' (Warford 2011:254).
Internalisation	In a Vygotskyan parlance, learning first occurs on a social plane (CL during the SLP) and then on an internal plane, through internalisation. Participating teachers were required to reflect and keep a journal. Sometime after the SLP, they were expected to provide an evidence-based portfolio in order to show the achievement of their learning goals. The reason was to ensure that teachers did not simply abandon the new skills or strategies that they were exposed to 'for what they perceive as the real world of teaching' (Warford 2011:255).
Recursion	Warford (2011:255) describes this phase as the 'theory into practice stage, where the dichotomy of theory and practice is confronted in all its intensity' [slightly paraphrased]. Here the teachers needed to illustrate some equilibrium, namely, that new concepts had been accommodated into conceptual understanding in order to solve their identified problems. The portfolios were designed to provide teachers the opportunity to showcase their reformed teaching practices, for example, by providing lesson plans and reflections on presented lessons.

Source: Warford (2011:254).
ZPTD, zone of proximal teacher development; SLP, short learning programme.

Self-directed learning as part of the professional development of teachers

Self-directed learning, where the learners take responsibility for their own learning, became a popular term worldwide to replace education systems that emphasised teacher-centred approaches, memorisation and rote learning, which do not foster student attributes needed for the 21st century.

To change an education system (such as the one in South Africa) where teachers rely mainly on teacher-centred teaching-and-learning strategies, it is necessary to first change teachers' established practices through professional development SLPs. According to Knowles (1975), self-directed learners have the urge to grow, and that is exactly what we wanted teachers to achieve during the professional development SLPs. We wanted them to grow as self-directed learners who can identify their own learning needs and, accordingly, formulate learning goals that they wish to achieve. In addition, these teachers should be capable of finding their own learning resources to achieve their goals. These resources could be other teachers, Internet materials, knowledgeable people in the community or any other source. Teachers need to have the skills to select appropriate learning strategies to satisfy their learning needs according to the available information and resources. Lastly, they need evaluation skills to determine if their selection indeed satisfies their learning needs. This process, according to Knowles (1975), is what SDL is all about.

Long and Associates (2000) identify four different conceptualisations of SDL, which can shed more light on the definition of SDL. Only one of these conceptualisations, the psychological conceptualisation, addresses the internal processes related to SDL. These authors explain three primary dimensions (motivation, metacognition and self-regulation) and four secondary dimensions (choice, competence, control and confidence), which are part of a psychological conceptualisation of SDL. Long and Associates (2000) also indicate how any learners, whether they are part of a group or working individually, need to employ these different dimensions in order to engage in SDL. Before teachers can foster SDL in their students, they actually need to become self-directed learners themselves, skilfully employing the different dimensions in their own learning.

Vygotsky's ZPD, and especially Warford's ZPTD, formed the framework of the SLPs (Table 3.1). This framework is well aligned with Knowles's (1975; Warford 2011:254) views on SDL – as well as

Long's (2000) primary and secondary dimensions – as it promotes teachers':

> [*C*]hoice(s) in determining the course of their own growth, it motivates them to think creatively about active learning strategies and it fosters intentional reflection on the learning situation. The more they experience success with active learning strategies the more they gain confidence in their practices. The tools should aid them in identifying, planning, selecting, designing, analysing, and reflecting. (p. 18)

According to Guglielmino's (1978:73) Delphi survey results, self-directed learners are persistent in learning, view problems as challenges, have a strong desire to learn, are always curious to learn more, and are goal-directed – to name a few characteristics. The SLPs for professional development of teachers should specifically aim to foster a desire to learn and to develop new student-centred active learning strategies. The aim is not to simply learn one or two strategies to replace the old teacher-centred strategies, but to improvise and develop new creative strategies and to realise that there is a plethora of ideas for keeping students actively involved in their own learning.

When developing a professional development SLP for teachers, which aims to foster SDL, the developers should constantly plan to achieve SDL characteristics among teachers. A paradigm shift from transmission-mode teaching and learning to SDL is needed, where teachers are willing to take up their responsibility as self-directed educators and constantly look for new and innovative ideas to get learners actively involved in their own learning. This professional development should not only better prepare teachers for their future role as self-directed educators but also equip them to foster SDL among learners.

Professional development courses for teachers should create a climate that promotes SDL and develops teachers' ability to steer further learning on their own. They should continuously be able to identify their own challenges in the classroom, set their own professional development goals accordingly, identify or improvise the necessary resources, implement the appropriate strategies, and critically reflect on and evaluate the process.

In doing so, they will also realise the advantages of this process for their learners (De Beer & Mentz 2017). These SLPs should provide teachers with opportunities to engage in their own learning and eventually feel confident about their own learning.

Cultural-Historical Activity Theory as a research lens

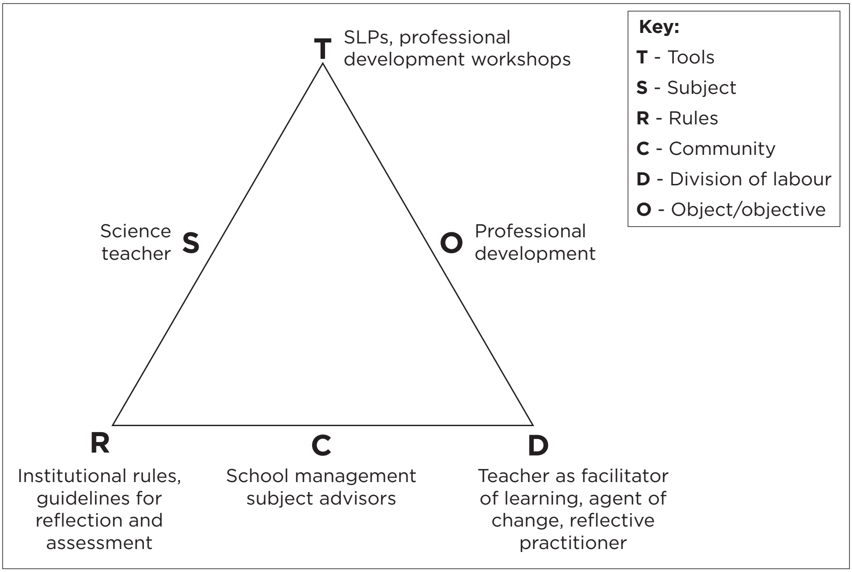
Cultural-Historical Activity Theory has its roots in social constructivism, and its development as a research lens was predominantly influenced by the work of Lev Vygotsky. Vygotsky (1978) emphasised the role of psychological tools and signs (e.g. language) in teaching and learning. Third-generation CHAT is a practical research tool that can assist the researcher in interpreting data embedded in specific cultural and historical contexts. This provides researchers the opportunity to better compare research findings from different contexts, as CHAT clearly shows the similarities and differences that characterise different research studies (as will be illustrated in this chapter).

Cultural-Historical Activity Theory has become popular as a research lens owing to, among others, its flexibility (Mentz & De Beer 2017). Rogoff (1995) alerted researchers to the fact that CHAT can be used on three different levels:

1. on a personal level or plane, where the focus is on the activity of an individual (the 'subject' in the activity system)
2. on an interpersonal plane, where more than one 'subject' is present, for example, the interplay between a teacher's teaching activities and a student's learning (with the teacher and learner as the two 'subjects' in the activity system)
3. on an institutional plane, where the focus is on a phenomenon (as the 'subject') and not on a real person.

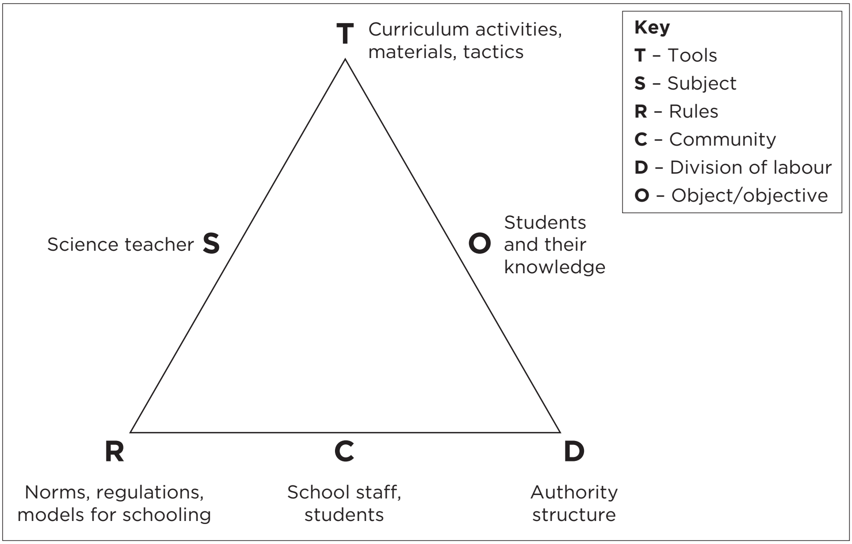
An example of the latter is the use of 'Indigenous Knowledge Systems' and 'school science teaching' as the 'subjects' of an activity system (De Beer & Mentz 2017). Beatty and Feldman (2012) indicate that CHAT is, therefore, a versatile tool that can be used in different ways. However, the criteria for a particular use of CHAT should be well explained and consistently applied. Figure 3.1 to Figure 3.4 illustrate the use of CHAT in these three contexts.

In Figure 3.2, Beatty and Feldman look at the interaction between the teacher (the 'subject') and the learner (the 'object') in an activity system (e.g. the classroom). We are of the opinion that comparing two interdependent activity systems, in which the teacher is the 'subject' in one activity system and the learner is the 'subject' in the other activity system, gives a far more nuanced perspective on the realisation of the 'object' in the



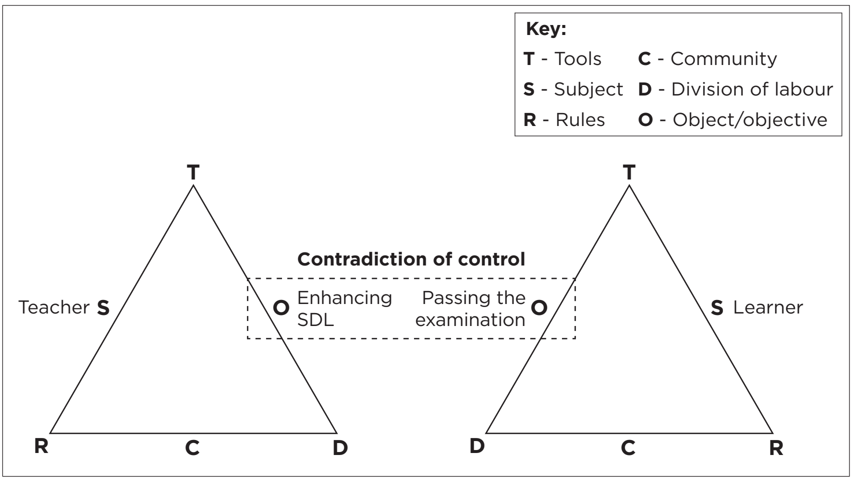
Source: De Beer and Mentz (2017:11).
SLP, short learning programme.
Note: The 'subject' in Figure 3.1 is the science teacher, and the 'object' is his or her professional development. 'Tools' include SLPs, professional development workshops, resources (e.g. books and knowledgeable people) and reflection. 'Rules' refer to institutional rules (e.g. university admission criteria for SLPs), guidelines for effective reflection, assessment, etc. The 'community' constitutes stakeholders such as subject advisors or school management (e.g. how supportive is school leadership of professional development activities for teachers). The 'division of labour' refers to the different roles of the teacher, for example, the teacher as a facilitator of learning, the teacher as an agent of change, the teacher as a self-directed learner or the teacher as a reflective practitioner.

FIGURE 3.1: The use of CHAT on a personal level.



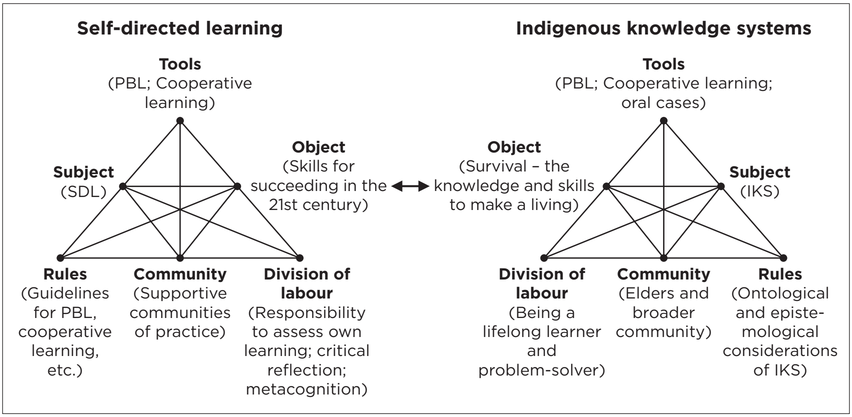
Source: Beatty and Feldman (2012:292).

FIGURE 3.2: The unconventional way of using CHAT on an interpersonal plane.



Source: De Beer and Mentz (2017:11).
SDL, self-directed learning.

FIGURE 3.3: Mentz and De Beer's (2017) use of CHAT on the interpersonal plane.



Source: De Beer and Mentz (2016).
IKS, indigenous knowledge systems; PBL, problem-based learning; SDL, self-directed learning.
FIGURE 3.4: The use of CHAT on an institutional plane.

activity system (Figure 3.3). Beatty and Feldman's approach does not make provision for a nuanced analysis of the teacher and learners' use of 'tools' or the different perspectives on 'rules' and 'division of labour'.

In the activity system on the left, the 'subject' is the teacher. The learner constitutes the 'subject' in the right-hand activity system. This, more nuanced, CHAT perspective on an interpersonal plane highlights the so-called 'contradiction of control'. While the teacher might plan to promote SDL in the classroom ('object' in the activity system on the left), the learners might work towards an 'object' of passing the examination (activity system on the right).

In Figure 3.4, the 'subject' is not a person, but an entity or a construct. In this figure, the respective 'subjects' are SDL (activity system on the left) and IKS (activity system on the right). There is a shared 'object' between SDL and IK, namely, the development of skills to sustain meaningful learning. The 'object' in the case of SDL (activity system on the left) is the development of 21st-century skills. The 'object' in the case of IKS (activity system on the right) is to provide holders of IK with skills to survive.

Later in this chapter, we refer to 'tensions' that arise in an activity system. However, the purpose of Figure 3.1 to Figure 3.4 is to illustrate the different contexts in which CHAT can be used, and not to analyse specific data or to identify 'tensions'.

The unit of analysis in CHAT is always human behaviour within a given context and demarcated by an activity system. Engeström (1987) coined the construct 'activity system'. This construct can assist a researcher in understanding how people are embedded within a sociocultural context, which they continuously interact with. A classroom could, for example, serve as an activity system. Likewise, young people learning about their IK in an authentic setting can also be viewed as an activity system.

The Vygotskyan scholar Luria (1981) explained that:

> [/]n order to explain the highly complex forms of human consciousness one must go beyond the human organism. One must seek the origins of conscious activity [...] in the social and historical forms of human existence. (p. 25)

Within an activity system (Figure 3.1), there is always a 'subject', for example, the Natural Science teacher; an 'object', which is the goal of the activity, for example, the teacher's professional development and SDL enhancement; 'tools' that facilitate the realisation of the 'object', for example, the pedagogy used to promote contextualised PBL and CL in the science classroom; 'rules' at play in the activity system, for example, curriculum guidelines or epistemological perspectives; a 'community' (all stakeholders involved in the activity system who might either support or prevent the 'object' from being achieved); and the 'division of labour' (the different roles played by the protagonist or subject).

Worldwide, many researchers use CHAT as a research lens. However, CHAT is especially valuable in complex situations, where several cultural and historical factors are at play. De Oliveira and Rego (2010) show how activity theorists, such as Luria, worked in contexts that were characterised by complexity and transformation. Cultural-Historical Activity Theory was developed during the Russian Revolution, a period when 'an entire generation was infused with the energy of revolutionary change' (De Oliveira & Rego 2010:4). The researchers Luria and his colleagues often worked with marginalised groups in the community. Cultural-Historical Activity Theory is thus an appropriate lens to use when researching South African education, which has been characterised by constant transformation since the birth of democracy in 1994. In a country where social justice issues are paramount, CHAT as a lens has the potential to provide insight into complex activity systems. Cultural-Historical Activity Theory is, therefore, very much applicable to the context of IK research, as IK is often marginalised owing to the educational focus on universal Western knowledge. An example that illustrates this statement is that, under the apartheid regime in South Africa, all forms of divination were outlawed under the *Suppression of Witchcraft Act* of 1957. Divination is at the heart of many healing practices in Africa (Ashforth 2005; De Beer & Whitlock 2009).

Engeström (2009) makes it clear that a researcher should always take two interdependent activity systems as the minimal unit of analysis. The researcher will thus juxtapose two activity systems, focussing specifically on the 'objects' of the two activity systems. Literature shows that the 'object' is normally surrounded by complexity, and McNeil (2013) speaks of a 'contradiction of control'. In this chapter, CHAT is used as a research lens to juxtapose two activity systems, that is, teacher professional development interventions in the Limpopo Province and the Northern Cape Province of South Africa, respectively (Figure 3.5). This chapter claims that the complexity surrounding the 'objects' of two interdependent activity systems is, to a large extent, influenced by the 'rules', 'tools' and 'division of labour' nodes in the activity systems, and that an analysis of these nodes could shed light on the 'contradiction of control' that often influences the realisation of the 'object'.

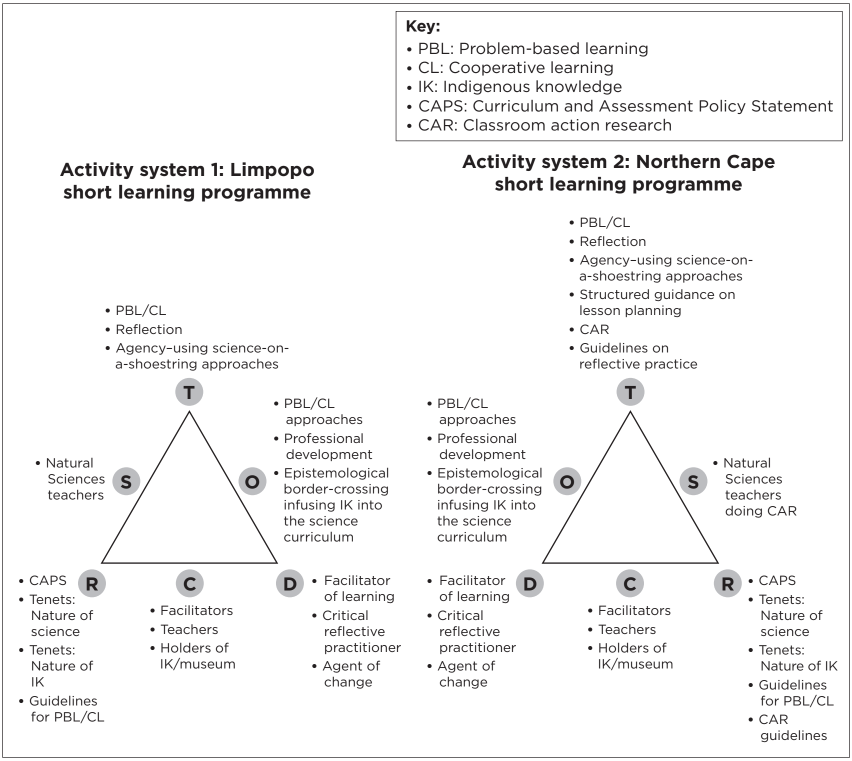


FIGURE 3.5: Cultural-Historical Activity Theory used as a lens to depict the Limpopo SLPs (left) and the Northern Cape SLPs (right).

Background to the Limpopo and Northern Cape interventions

This is a DBR project. In subsequent chapters, data will be shared on the SLPs in which STEM teachers engaged with IK. Chapter 5 deals with Natural Sciences, Chapter 6 with Mathematics and Chapter 7 with technology. However, the focus of this chapter is on the use of CHAT as a research lens, as CHAT will also be used as a research lens in other chapters. Sari and Herrington (2013:122) argue that DBR allows the researcher to focus on complex problems and, from the data, distil design principles to improve an intervention. Design-based research is, therefore, characterised by a long-term engagement that involves intensive collaboration. In this specific context, DBR allows for continuous improvement of the SLPs, where data obtained after a SLP assist the facilitators in distilling new design principles and redesigning future SLPs in order to better serve the teachers' needs and achieve the outcomes.

The Limpopo intervention (Cycle 1 in this design-based research)

In 2016, a three-day SLP was presented to 62 Life Sciences teachers in Polokwane in the Limpopo province. The aim of the SLP was to provide teachers with a better understanding of how the curriculum could be made more relevant to diverse learners by infusing cultural (indigenous) knowledge into curriculum themes.[5] We were mindful of depicting the shared tenets of both science and IK in the SLP, so that teachers could better facilitate such border-crossing in their classrooms. Cronje, De Beer and Ankiewicz (2015:323–324) show that both the Natural Sciences and IK share tenets such as their empirical, tentative and inferential nature. Underpinning IKS are two important considerations. Firstly, De Beer and Mentz (2017) show that many holders of IK were (and still are) self-directed learners who need to solve complex problems in their immediate environments, often to ensure survival (Ch. 3). Problem-based (inquiry) learning is, therefore, a shared characteristic of both science and IK and was, therefore, emphasised during the SLP.

Secondly, IK is collective knowledge, and Jautse, Thambe and De Beer (2016) show that CL is an appropriate strategy to facilitate IK as it honours its syntactical nature. Thus, teachers explored the antimicrobial qualities of medicinal plants in the laboratory using an

5. A short YouTube video on the intervention can be viewed at: https://www.youtube.com/watch?v=hrA3_MpsA2Q

adapted Kirby–Bauer technique (Mitchell & Cater 2000), working in small groups of four teachers. Examples from mostly Khoi-san origin were used as illustration. The learning task was conceptualised being mindful of providing teachers with the opportunity to set 'driving questions' themselves (Krajcik & Shin 2016), which would guide their inquiry. The five basic principles for CL that were identified by Johnson, Johnson and Smith (1998), and Johnson and Johnson (2014), namely, positive interdependence among group members, face-to-face promotive interaction, individual accountability, interpersonal small-group skills and group processing, were implemented. Apart from engaging in the laboratory task, teachers (within their groups) had to plan lessons, which formed part of the portfolios that they needed to submit within six months after completion of the SLP. The aim was to provide not only a once-off training opportunity but also to allow teachers to grow and reflect on their experiences. They had to think creatively about how they would address other sections of the CAPS in similarly innovative ways in order to actively engage learners in their learning. For example, teachers had to provide lesson plans in the portfolios that addressed IK by making use of CL or PBL. These portfolios were assessed, and teachers received feedback after submission. Furthermore, presenters of the SLPs visited these teachers after a period of six months to follow up with ideas and guide them in their efforts to become self-directed teachers.

The Northern Cape intervention (Cycle 2 in this design-based research)

In the second half of 2017, Cycle 2 of the DBR started, with a SLP in Calvinia in the Northern Cape.[6] Thirty-seven Life and Natural Sciences teachers participated in this intervention. The same examples from the Khoi-san culture, as mentioned in the Limpopo intervention, were used. Teachers were afforded six months after the course to submit

6. A short YouTube video can be watched at this link: https://www.youtube.com/watch?v=01qezHXsJSs.

their portfolio, which was similar to the Limpopo portfolio assignment, but with greater emphasis on Classroom Action Research (CAR). This was done in an attempt to enhance the development of reflective skills among teachers – a design principle that was distilled in response to the poor and superficial evidence of reflective practice in the Limpopo portfolios. Mettetal (2002) describes CAR as a midpoint between teacher reflection and traditional educational research. Gravett and De Beer (2015) emphasise that CAR is more data-based and systematic than reflection but also less formal and controlled than normal educational research.

Research methods

As mentioned earlier, this chapter focuses on the use of CHAT as a lens in researching the professional development of science teachers and their ability to facilitate epistemological border-crossing between IK and the Western science curricula. A gap that was identified in the research literature was that little has been published on the 'rules', 'tools' and 'division of labour' nodes in an activity system. Therefore, the research question that guided this chapter was: How can the 'rules', 'tools' and 'division of labour' nodes within two activity systems provide better insight into the 'contradiction of control' that often characterises activity systems?.

Based on earlier work (Mentz & De Beer 2017), the authors used third-generation CHAT as a lens to view two teacher professional development interventions in the Limpopo and Northern Cape provinces of South Africa, respectively. The two activity systems juxtaposed in Figure 3.5 are:

1. the 2-day SLP offered to teachers when the interventions commenced
2. teachers' individual classroom experiences after the intervention.

The focus was on the transfer that took place after the SLPs (Figure 3.6). In each of these two figures, the two activity systems compared are the Limpopo SLP (on the left-hand side) and the

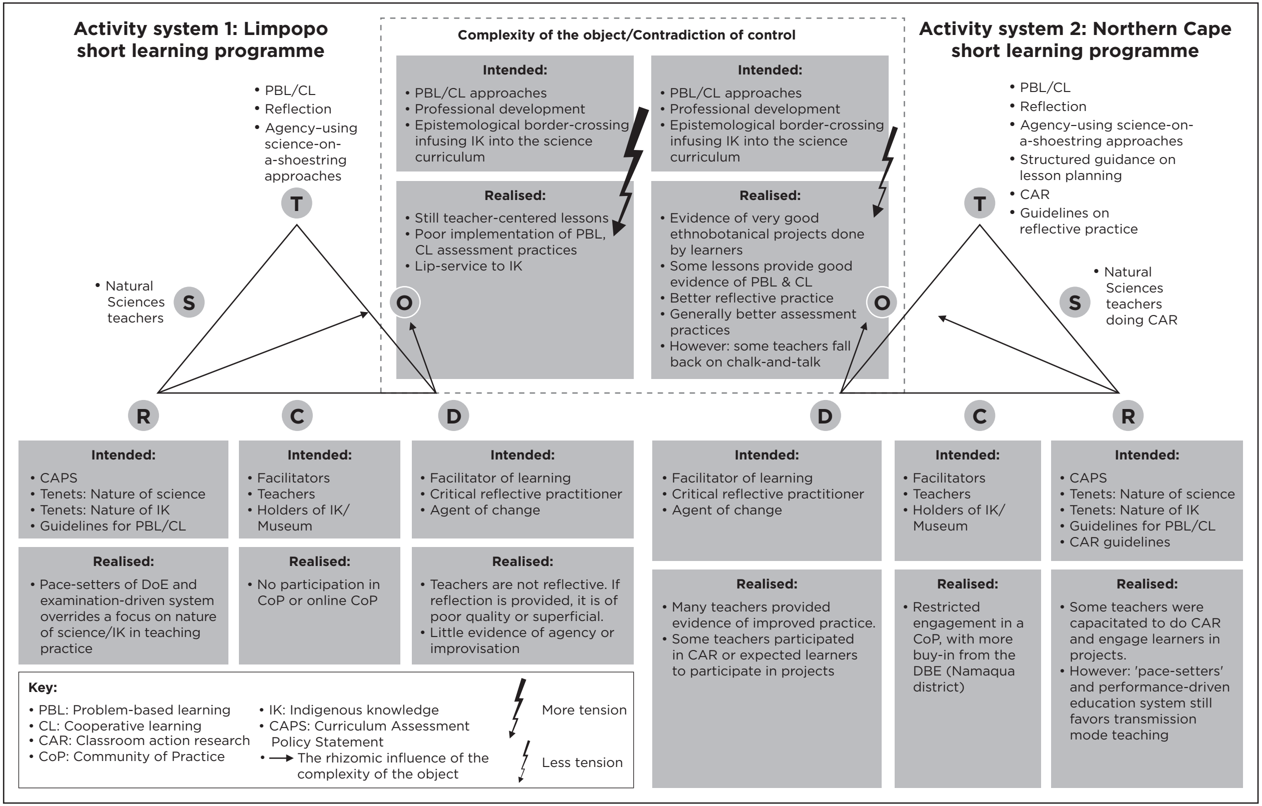


FIGURE 3.6: Cultural-Historical Activity Theory used as a lens to study the post-intervention transfer to classrooms in Limpopo (left) and the Northern Cape (right).

Northern Cape SLP (on the right-hand side) after a number of new design principles were implemented. Data were collected through the analysis of teacher portfolios (with lesson plans), individual and focus group interviews with teachers and the analysis of artefacts (e.g. learner assignments). Emerging themes were identified, which were further analysed using a CHAT lens.

Findings

The findings in this section are reported on in the following manner: we start by briefly explaining the major trends emerging from the intervention data in the Limpopo and Northern Cape provinces. Cultural-Historical Activity Theory was used to interpret the data from Cycle 1 (after the Limpopo intervention). These insights were then used to revise the SLP for Cycle 2 (Northern Cape intervention). Teachers participating in the SLP in the Northern Cape benefitted, therefore, from the predictive value of CHAT. We then juxtaposed the two activity systems and, by using CHAT, distilled a number of emerging themes. These insights will dictate future interventions, as we claim that CHAT holds predictive value.

The Limpopo short learning programme (Cycle 1)

Disappointing portfolios

Despite the very positive feedback from the teachers after the SLP, we were disappointed by many of the portfolios that we received back. It was also disconcerting that the majority of teachers did not submit their portfolios within six months after completion of the SLP. Only 24 of the 62 teachers (39%) qualified for certificates. Of these teachers, seven obtained distinctions, and these teachers' portfolios provided very good evidence of creative transfer of newly acquired knowledge and skills into the classroom. The other 17 portfolios were a mixed-bag in terms of quality: six portfolios included lesson plans that provided evidence of sound PBL and CL, and included IK in an authentic way.

The other 11 portfolios provided evidence of what Warford (2011:255) describes as 'discard(ing) the academy for what they perceive as the *real world* of teaching'. Zeichner and Tabachnick (1981:7) speak of the 'wash-out' effect; 'newly acquired knowledge and skills obtained during teacher education programmes are often "washed out" at the coalface of teaching in the classroom'.

Research sub-themes that emerged from the portfolios and interviews with Limpopo teachers

The SLP facilitators were very disappointed with the relatively poor quality of portfolios submitted by teachers from the Limpopo intervention. The following excerpt from one of the submitted portfolios illustrates the underdeveloped subject and pedagogical knowledge of the teacher, as well as the lack of knowledge of basic laboratory equipment and procedures (Table 3.2).

Most of the personal interviews that were conducted indicated that the teachers needed more guidance and professional development to effectively incorporate IK in their classrooms. One of the teachers commented, '[w]ith IKS we have to go out to museums or IK practitioners, and if I go away for the day the learners that stay here don't have guidance' (teacher responses,

TABLE 3.2: Example of a laboratory report – Limpopo cohort.

Excerpt from teacher portfolio	Notes from the researchers
Laboratory report: Kirby–Bauer technique - Pump organisms in the plate - Sterilise hockey stick with 95% ethanol - Flame hockey stick - Take antibiotic discs and put them inside the plant sample - Incubate at 37 degrees.	The lack of scientific terminology is cause for concern. 'Pump organisms' (referring to 'inoculate organisms') and 'hockey stick' (referring to 'inoculation needles' used in microbiology labs) provide evidence that this teacher is not properly trained in laboratory work. This begs the question: How can this teacher possibly portray the tenets of the nature of science in the classroom?

Source: Portfolio of one of the teacher participants, used with her permission.

date unknown, location unknown). As most science teachers were never trained in epistemological border-crossing between science and IK, many of them resort to excursions with learners, such as a day-trip to a relevant museum, but this creates problems, such as classes that are cancelled at school.

Another problem that was flagged by the teachers was the full curriculum and lack of time to engage learners in inquiry learning, as can be seen from the following comment:

> 'There is a lot of content and they [*Department of Education*] increased it'; 'I was so inspired by what we have learned in the short course, but I am afraid that I will not have enough time to do it in my classroom. The test on *muthi* plants takes a lot of time, and I have to keep to the pace setter'. (Teacher responses, date unknown, location unknown)

The data obtained from the portfolios and personal interviews indicate the need for more systemic and longitudinal solutions, involving the Department of Basic Education in collaboration with training institutions, to support continuous professional development in the form of regular visits, organising communities of practice, and assisting teachers to obtain learning materials where Internet connections are not available.

Design principles that were distilled from the data

In true DBR fashion, we made changes to the SLPs to address problems that were identified. The data prompted the researchers to revisit the SLP, and to redesign the SLP to try and ensure better transfer to the classroom. Of particular concern was the fact that many teachers did not submit their portfolios, despite several reminders from the university. A number of design principles were distilled in Cycle 1, which informed the second cycle (Northern Cape). These design principles included:

- We realised that teachers in rural Limpopo schools do not often enjoy the benefit of supportive communities of practice that scaffold their learning and professional development.

After the three-day SLP offered in Limpopo, teachers did not receive much support from the facilitators as we were awaiting their portfolios. Only when we received the portfolios, months later, did we become aware of the challenges that these teachers faced. It was realised that these teachers were in need of an online Community of Practice (CoP) whereby they could engage in peer mentoring. It was also realised that a closer liaison with the Department of Basic Education was essential in order to provide the necessary follow-up support.

- In at least 60% of the portfolios, teachers either did not provide any reflections on their lessons or they provided very superficial or naïve reflections. A number of teachers provided lesson plans that showed transmission-mode approaches (chalk-and-talk), yet the teachers would reflect that the lesson was very successful and that it engaged learners and provided them with a better understanding of the NOS. The facilitators made an incorrect assumption prior to the Limpopo SLP, that is, that these teachers were reflective practitioners. Because of this assumption, very little time was devoted to reflection during the SLP. A design principle that was distilled from the Limpopo data was that more attention should be given to critical reflective practice during the SLP. One way of doing this would be to empower teachers to participate in CAR — a strategy that was implemented in Cycle 2.
- Despite the fact that teachers in Limpopo were shown the benefits of 'frugal science' (Ahuja 2014; Jackson, De Beer & White 2018), an approach using cheap and accessible scientific tools in under-resourced classrooms (also known as 'science-on-a-shoestring'), we saw very little evidence in the portfolios of frugal-science improvisation. One reason could be that the facilitators provided answers to questions that the teachers themselves had not yet asked. A far better approach would have been to base a frugal-science activity on the teachers' everyday experiences of teaching science in an under-resourced classroom and then letting them set development goals for themselves. Another design principle that was distilled was the need to encourage such teacher

agency during the SLP in order to enable teachers to devise such materials and approaches, and to transfer this new knowledge to different situations. However, this approach would have to be contextualised in terms of the teachers' own needs, and that they themselves should identify this as a learning goal.

- Teachers commented in their portfolios, and during the personal interviews, that the SLP did not equip them for the wide learner diversity in their classrooms. Teachers reflected on the cultural diversity in their classrooms (Bapedi, Batswana and Vhavenda, among others), yet most of the examples used during the SLP were (unfamiliar) Khoi-san in nature. Two design principles emerged from this realisation. Firstly, more relevant examples should be provided during the SLPs, taking local context into consideration. Secondly, although the facilitators and researchers thought that it was clear that the central premise of the SLP was that teachers should behave as self-directed learners and learn more about specific cultural groups present in their classrooms, this was not the case. Another design principle identified was, therefore, to explicitly discuss SDL during the SLP.

The Northern Cape short learning programme (Cycle 2)

An emphasis on project-based learning and classroom action research

Based on the insights gained from Cycle 1, the SLP was amended to incorporate the above-mentioned design principles. An important lesson learnt during the Limpopo intervention was not to make assumptions about the knowledge and skills of participating teachers. In an attempt to address the problems of lack of inquiry learning and lack of teacher reflection displayed in many of the Limpopo portfolios, project-based learning and CAR were prioritised during the SLP in Cycle 2. The basic principles that were emphasised during the SLP in Cycle 2 are summarised in Table 3.3.

TABLE 3.3: Basic principles of PBL and CAR emphasised during the SLPs in Cycle 2.

PBL	CAR
Teachers were introduced to the six key features of project-based learning, as explained by Krajcik and Shin (2016: 275–276):	Teachers were introduced to the steps in CAR, as described by Gravett and De Beer (2015:347):
1. A driving question should be formulated (a problem should be solved). 2. Learners should demonstrate mastery of key science standards or outcomes. 3. Learners 'explore the driving question by participating in scientific practices' (problem-solving) (Krajcik & Shin 2016:276). 4. Learners, teachers and community members 'engage in collaborative activities to find solutions to the driving question' (Krajcik & Shin 2016:276). 5. In the learning process, student learning is scaffolded. 6. Learners 'create a set of tangible products that address the driving question' (Krajcik & Shin 2016:276).	1. The teacher should identify a problem and formulate a research question. 2. The teacher should plan an intervention or lesson or approach as a possible solution to the above problem. 3. The teacher should act and collect data (evidence). 4. The teacher should analyse the data. 5. The intervention (project or lesson) should be evaluated in order to determine whether the problem was addressed/research question answered.
Teachers could plan and implement any project in their classrooms. As the ethnobotanical survey was discussed during the SLP, the majority of teachers implemented such project-based learning interventions. However, teachers also identified several highly relevant projects, for example, a project on water quality in an area that faced a devastating drought.	Teachers were encouraged to formulate research questions such as, 'What are learners' experiences of engaging in project-based learning?', focussing, therefore, mostly on affective factors such as student interest.

Source: The project-based learning principles are adapted from Krajcik and Shin (2016); the rest of the work in this table is that of the authors.
CAR, classroom action research.

☐ Portfolios provided evidence of reflective practice, and there were good examples of effective incorporation of indigenous knowledge into science themes

Many of the Northern Cape portfolios provided evidence of effective incorporation of IK into CAPS themes. Table 3.4 provides an example in which a teacher in Calvinia contextualised DNA technology.

TABLE 3.4: Lesson in which a teacher incorporated IK into DNA technology.

Lesson topic:	**DNA Technology: Extracting DNA from plant tissue.**
Duration:	**90 min.**
Teacher's activities	**Learners' activities**
Introduction I will ask learners to provide examples of how DNA technology finds application in our everyday lives.	Learners will discuss the application of DNA technology in small groups. Learners will be encouraged to Google information on their cell phones. After 10 min, groups will provide feedback.
Consolidation of learners' feedback Based on learners' feedback, I will provide a short overview of the application of DNA technology (e.g. DNA Barcoding), such as the authentication of medicinal and herbal products, invasive and alien species, and wildlife crime.	A question-and-answer session, in which learners will be allowed to think of examples of these applications, for example, instances of wildlife crimes like rhino pouching.
Contextualising the lab activity: I will provide the following background to this lab: From time to time, patients die when they take the medicines given to them by traditional healers. It is, therefore, necessary to sometimes do DNA Barcoding, to determine what plant- and animal species were used in making these traditional medicines. Today, we are going to extract DNA from bananas.	
Lab: Extracting DNA from bananas I will utilise a 'shoestring-approach', where learners will extract DNA from plant materials such as bananas. **Note by the authors:** The teacher then explains the process that will be scaffolded in the classroom.	Learners engage in practical work in the laboratory.
Lab report (assessment) Learners will be asked to do the lab report in a different way, namely, in the form of an article for a scientific journal.	Learners are asked to first study a few examples of journal articles, and they then, in their small groups, need to plan and write an article.

Source: Submitted teacher portfolio, which forms part of our data.

Another example of the effective incorporation of IK into curriculum themes is a lesson and practical activity on making *boerseep* (traditional soap) that was included in one of the portfolios. The teacher concluded:

> My research led me to uncover that in the olden days Asbos (a Karoo vygie) was burned to get loog (lye) and this was used instead of

caustic soda. In comparison, the method used in the olden days to make soap took at times a whole day stirring the mixture over an open fire. Therefore, caustic soda hastens the process of making soap. (Teacher responses, date unknown, location unknown)

The teacher then engaged her learners in a practical activity where they used caustic soda to make soap.

Inquiry learning (problem-based learning) was more evident in the Northern Cape portfolios

Table 3.5 is an excerpt from a lesson plan that provides evidence of inquiry learning. This lesson plan served as an introduction to a learner project on conducting an ethnobotanical survey.

TABLE 3.5: An excerpt from a lesson plan that provides evidence of a shift towards inquiry approaches [Translated from Afrikaans by the researchers].

Lesson topic:	**How do we preserve the rich IK of the *Hantam* area?**
Duration:	**40 min (series of lessons, introducing the project)**
Teacher activities	**Learner activities**
I will show learners a photograph of a well-known traditional healer in Calvinia who died two years ago (who should be well-known to many learners). This IK is often not written up, and as IK is an oral tradition, it can easily become lost to future generations. What can we do to preserve this knowledge? (Give the learners a chance to discuss this in small groups.)	Learners are provided an opportunity to discuss the loss of IKS in small groups. Every learner is assigned a responsibility, for example, making notes or reporting back to the class.
After groups have provided feedback, I will provide the learners with an opportunity to plan (in groups of four) an ethnobotanical survey. I will scaffold their learning and provide inputs as needed.	Learners engage in planning an ethnobotanical survey.
I will provide the learners with an article by researchers on how such surveys can be conducted.	In their groups, learners now have to assess their project outlines, by working through the provided article and measuring their own plans against the suggested steps.

Source: Data from one of the teacher portfolios.
IK, indigenous knowledge.

The portfolios and interviews provided evidence of self-directed learning and classroom innovation

In one of the interviews, a teacher commented on how the SLP had inspired her to do further research on the use of music to teach curriculum content. This was actually not a focus of the SLP, and was merely mentioned in passing, yet the teacher displayed SDL:

> I can read music and play the piano. I take Nicholas Louw [*a popular South African artist*] songs that I like, and then write lyrics that are relevant to curriculum themes. I then sing it in my lessons. This motivates the learners. (A teacher, gender undisclosed, date unknown; [*translated from Afrikaans*])

Another example of SDL was provided by a teacher who realised that she needed to improve her knowledge of local flora. She identified an expert (from a local farm) to scaffold her learning, and, with his help, she implemented a very successful ethnobotanical survey project in her class. A third example (emerging from a teacher's portfolio and an interview with her) was a learning activity in which learners used frugal science to learn about electricity. Learners had to build a torch light making use of cheap resources such as a toilet roll, flashlight, wire and a battery. The teacher commented that '[...] they were very excited – they were actively participating [translated from Afrikaans]' (teacher responses, date unknown, location unknown).

Using Cultural-Historical Activity Theory as a lens when juxtaposing two activity systems

As mentioned, the Northern Cape teachers enjoyed the benefits of an improved SLP owing to the predictive value of CHAT. The differences between the two SLPs are shown in Figure 3.5. Although the basic structure of the two SLPs was very similar, the second SLP included a stronger focus on reflection and engagement in CAR. Figure 3.5 shows the two activity systems, which depict the Limpopo SLP (triangle on the left) and the Northern Cape SLP (triangle on the right).

Based on the data obtained, Figure 3.6 shows two activity systems that represent classroom transfer after the SLP in Limpopo (left) and the Northern Cape (right). The data that informed the activity systems in Figure 3.6 came from teacher portfolios, interviews and classroom observations. We need to state upfront that in both activity systems there were exceptions to the general trend, that is, a few excellent examples of reflection, inquiry learning and effective border-crossing in Limpopo classrooms, and teacher-dominated 'chalk-and-talk' lessons in the Northern Cape. However, Figure 3.6 provides an overview of the general trends observed.

Themes that emerged using this CHAT perspective are in the following sections.

Theme 1: Local context should be taken into consideration during the short learning programmes to best serve the 'object' in the activity system

During Cycle 1 (Limpopo SLP), the facilitators used mainly Khoi-san IK examples. One of the Limpopo teachers commented afterwards that 'although the course was very interesting, it did not provide us with many examples relevant in the Limpopo province' (teacher responses, date unknown, location unknown). Such Khoi-san examples, however, were very relevant in the Northern Cape (Cycle 2), as this area was once the home of many Khoi-san people. De Beer and Van Wyk (2011) have described the rich ethnobotanical knowledge of Khoi-san descendants in the Northern Cape. De Beer and Mentz (2017) showed that school children in the region also take a keen interest in the flora. The latter authors (De Beer & Mentz 2017) showed that the children especially knew the names of edible plants, which the authors explain in terms of the fact that the area is generally socio-economically stressed and that veld food provides a means of sustenance. Interestingly, older children had also started to learn the names and uses of medicinal plants (De Beer & Mentz 2017:7). The facilitators realised, therefore, that the Khoi-san examples that were unfamiliar to the teachers in Limpopo would be far more appropriate and relevant to teachers (and learners) in the Northern Cape.

One of the 'rules' in the activity systems is to portray the true nature of IK. The unfortunate choice of IK examples in Cycle 1 probably contributed to the 'contradiction of control' related to the 'object' in the Limpopo activity system. A 'realised object' in activity system 1 was that only lip service was paid to IK. Lesson plans on human anatomy and physiology included examples of medicinal plants, but the true tenets of IK were not addressed. This is in stark contrast to activity system 2, where IK was better infused into classroom teaching, as shown in the example above from a Cycle 2 portfolio. This particular teacher effectively infused IK into a particularly difficult curriculum theme, namely, DNA and biotechnology.

Another portfolio example was a Calvinia teacher's learning activity on traditional soap making and her experimentation with lye made from the asbos (*Mesembryanthemum junceum*). Traditionally, the asbos (a local plant) is burnt to provide alkali ash in soap making (Van Wyk & Gericke 2018). However, learners discovered that caustic soda is more effective. She incorporated the tenets of science into the lesson, engaging the learners in the so-called scientific method.

☐ Theme 2: A greater emphasis on problem-based and project-based learning is needed during the short learning programme in order to facilitate a shift from transmission-mode teaching towards inquiry approaches

As mentioned earlier, the facilitators realised (after Cycle 1 of the DBR) that no assumptions should be made about teachers' knowledge and skills. During Cycle 2, more focus was given to problem-based and project-based learning, and the local context was taken into consideration. This yielded good results. Although ‘chalk-and-talk’ lesson plans were still evident in the Northern Cape teachers’ portfolios, a clear shift could be seen towards inquiry approaches. Of the portfolios assessed, about 60% of the lesson plans had authentic elements of PBL. The example provided in Table 3.5 serves as an illustration. The Calvinia learners in one class had to plan an ethnobotanical survey, and their learning was scaffolded using the article by De Beer and Van Wyk (2011) on how to conduct ethnobotanical surveys. During this inquiry, the learners engaged in authentic science, and this led to the realisation of affective outcomes. In an interview, the teacher concerned commented:

> The Grade 10 class is actually a difficult class. It was therefore amazing for me to see how the learners participated and were engaged [...] they were excited about the project. (A teacher, gender undisclosed, date unknown; [*translated from Afrikaans*])

The ‘realised object’ in activity system 2 (Figure 3.2) included a better incorporation of inquiry (problem-based) learning. This was because of a focus on ‘tools’, that is, in the second SLP, more focus was given to PBL as compared to the first SLP. Also, the introduction of CAR catapulted the shift from transmission teaching towards inquiry approaches.

Theme 3: The development of the reflective skills of teachers should be prioritised during the short learning programmes

Although some Cycle 2 portfolios were still disappointing, owing either to the complete lack of reflection or the superficial nature of the reflection, a much larger percentage of portfolios (around 60%) provided evidence of more nuanced reflection as compared to Cycle 1. The Calvinia teacher, who engaged her learners in ethnobotanical surveys, provided a good example of critical reflection. She indicated that she would announce the project early next year and indicated how she would approach the project differently based on her experiences. She also critically reflected on her own knowledge and skills and identified the need to learn more about the local flora. Under 'division of labour' in activity system 1, it became clear that most teachers were not reflective practitioners. Although the 'tools' node indicates a focus on reflection during the SLP, this was done in a haphazard way, as the facilitators assumed that all teachers were reflective practitioners. In Cycle 2, a deliberate attempt was made to scaffold teacher reflection, and portfolios bear testament to a more nuanced reflection.

Theme 4: Teacher engagement in classroom action research provides affordances that should be emphasised during in-service teacher education

Realising that (1) the Northern Cape community has a closer link to local flora than many other regions in the country and (2) more should be done to enhance teacher reflection, the SLP designers provided the teachers in Cycle 2 with the opportunity to engage in CAR with a focus on the affordances of project-based learning in the classroom. Although teachers could choose any project for their learners to engage in, most teachers (whose portfolios have been assessed up to this point) chose ethnobotanical surveys as a project theme.

A number of the teachers produced excellent examples of project-based learning, which were skilfully packaged within their CAR reports. An example of good CAR was provided by a teacher in one of the high schools in the Hantam region. She wanted to determine how learners experience their engagement with ethnobotanical work. She gave the learners (working on small groups) a compulsory assignment on developing brochures for the different biomes in South Africa. However, she also provided her Grade 10 learners with an additional (optional) opportunity to perform an ethnobotanical survey and, to her surprise, many learners willingly participated. Her research question focussed on learners' experiences of engaging in such activities, and whether it led to affective outcomes such as interest in, and enjoyment of, Life Sciences. In a personal interview with the researchers, she stated:

> Despite the fact that I wanted to get hysterical at times about this ethnobotany study, it was also a big highlight. The Grade 10 class is actually a difficult class [...] It was amazing for me to see how they cooperate, and how they get excited about it. This gave me pleasure. (A teacher, female, date unknown; [*translated from Afrikaans*])

This emphasis on CAR and reflection in activity system 2 was one of the reasons why there is better alignment between the 'intended object' and the 'realised object', and not the same 'contradiction of control' as in activity system 1. Once again, the 'tools' used (e.g. CAR) supported the realisation of the 'object' of the activity. Again, the 'division of labour' highlighted the importance of the role of the teacher as reflective practitioner.

Theme 5: Careful consideration should be given in short learning programmes for enhancing self-directed learning

Candy (1991) is of the opinion that self-direction in learning is not necessarily a fixed quality that exists independently in an individual or in a situation. He argues that it is the result of the interaction between the person and the situation. It is, therefore, essential to create a learning environment during the SLP that fosters SDL. Whereas the reflections in activity system 1 were mostly superficial (with a few exceptions), more nuanced reflections characterised the reflections in the portfolios in activity system 2. The following excerpt, from a reflection in a Northern Cape teacher's portfolio, shows that SDL was developed in some of the teachers:

> It is so essential for a teacher to adapt her strategies to suit the needs of learners. Today's learners have different needs from those of 21 years ago, when I started teaching. However, the danger is that a teacher gets 'stuck' in habits and ways of doing things. This short

> learning programme provided new wind in my sails and a fresh outlook on teaching and learning. We have realised that the local environment (and its flora) is a resource that we need to tap into, and that we can facilitate problem-based and project-based learning with very few resources. However, we have also realised that we are not very knowledgeable about the plants in the Hantam. We have therefore asked an expert from the farm Tierhoek to assist us in addressing this knowledge gap. (A teacher, gender undisclosed, date unknown)

Not only did this teacher formulate learning goals for herself but she also identified resources to assist herself in obtaining these learning goals.

A more dedicated focus on strategies and approaches to enhance SDL in activity system 2 is clear from the 'tools', 'rules' and the 'division of labour' nodes. More activities, such as a focus on CAR, characterised the 'tools' in activity system 2. The role of the teacher as reflective practitioner is a prominent feature of the 'division of labour'. Guidance was provided to teachers on various ways to reflect, and they were also introduced to the steps in CAR, which could be seen as 'rules'. All of these created a learning environment more conducive to the development of SDL.

☐ But … still back to the drawing board

Despite the positive trends in Cycle 2, as reported above, there were still a sizeable number of teachers in the Northern Cape cohort who did not achieve the grade (in terms of meeting the criteria for obtaining the certification). Based on the predictive value of CHAT, the SLP for Cycle 3 could be changed to better facilitate the achievement of the 'object'. The CHAT lens highlighted a number of prevailing problems. Even in Cycle 2, there was little evidence of a sustained CoP. (This aspect is discussed in Chapter 9, where the authors recommend an online CoP and blended learning.) Although greater liaison with the Department of Education characterised Cycle 2, there is still scope for improvement. Too little was done during the SLP for teachers to have sufficient hands-on experience to apply new pedagogies to certain CAPS themes.

On a more optimistic note, one of the teachers indicated during the interview that she shared her new knowledge on De Bono's thinking hats (a CL activity used during the SLP) with colleagues who did not participate in the SLP. She indicated that they were very excited to use this CL strategy in their classrooms. This teacher clearly operates as a keystone species in this informal CoP – an aspect that should receive more attention in teacher professional development.

Discussion on the versatility of Cultural-Historical Activity Theory as a lens and the importance of the 'rules', 'division of labour' and 'tools' nodes

The intervention in Limpopo province highlighted the 'contradiction of control'. During the SLP, teachers were introduced to PBL and CL approaches that could enhance SDL (and the contextualisation of science through the infusion of IK into curriculum themes). However, during the post-intervention classroom visits, and in their portfolios (that included lesson plans), most of the teachers reverted back to transmission-mode teaching. We referred earlier to the fact that teachers sometimes discard the 'academy' for what is perceived as the 'real world of teaching'. In such a situation, CHAT can provide interesting insights and can help to identify possible causes. Firstly, teachers interviewed indicated that the 'pace-setters' (programmes of curriculum implementation) place them under time pressure. Consequently, they tended to revert to familiar 'chalk-and-talk' approaches, which are seen by them as being more effective in achieving the intended outcomes. There is, therefore, a tension between 'rules' and the realisation of the 'object' in the activity system. However, such a simplistic stance, which implies that it is only a systemic problem, is a skewed perspective. If one looks at the 'tools' in Figure 3.2, it becomes clear that the SLP did not provide the teachers with the opportunity to compare an inquiry-based or CL lesson with a traditional chalk-and-talk lesson.

If this was done, teachers might have realised that effective PBL or CL lessons do not necessarily require more time than traditional teacher-centred lessons. This is, therefore, a design flaw in the SLP itself, which should be addressed in future SLPs.

There is a second tension between the ‘rules’ node and the ‘object’. Although infusion of the nature of IK (which could be seen as a ‘rule’ to guide teaching and learning) was evident during the Limpopo intervention, it was not context-sensitive. Mostly, Khoi-san examples were used, with hardly any reference to Bapedi, Batswana and Vhavenda IK – the predominant cultures in Limpopo. Once again, this was a design flaw in the SLP. The SLP did not effectively prepare teachers for the reality that they would face in their classrooms in terms of student diversity.

Another tension that arose in the Limpopo activity system, which sheds light on the ‘contradiction of control’, is located within the ‘division of labour’ node. Many Limpopo teachers did not provide evidence of critical reflective practice in their portfolios. Such a lack of critical reflection can enforce the status quo (transmission-mode teaching) and lead to the ‘wash-out effect’ (Ziechner & Tabachnick 1981) mentioned earlier. Again, it can be asked whether or not the SLP provided sufficient support to the teachers to enable them to develop their skills as reflective practitioners. Whereas researchers could easily subscribe to the lack of transfer in the classroom to systemic (external) factors such as rigid ‘pace-setters’, CHAT provided a more nuanced perspective and alerted researchers to possible internal factors, such as design flaws within the SLP itself.

The data collected in the Northern Cape are promising in so far as there was better alignment between the ‘objects’ in the activity systems. Several teachers in the Northern Cape engaged learners in project-based learning and in CAR. However, the ‘contradiction of control’ was not entirely eradicated. In order to better understand this, we looked more closely at the ‘rules’ and ‘division of labour’ components of the activity systems. The data show that the systemic focus on learner achievement in summative examinations and rigid pace-setters provided by the Department of Basic Education ('rules') often discourage teachers from consistently following inquiry approaches. Again, as in the case of the Limpopo intervention, this suggests a design flaw in the SLP, which did not provide teachers with hands-on experience of discrediting this misconception regarding the 'tools'. Teachers also indicated that they did not have sufficient time to be more critically reflective as educators ('division of labour') and could not invest sufficient time in their own professional development. Despite the fact that the SLP designers aimed to establish effective communities of practice to support teachers (among others, in their reflection), this did not materialise well in both cycles. The major reason was that many of the teachers did not have sufficient access to the Internet (This aspect will be discussed in Ch. 9).

We need to highlight another important difference between the two activity systems. In the Northern Cape, where a large percentage of the population is of Khoi-san descent, people live in harmony with the environment and have good knowledge of ethnobotany. This aspect was capitalised on in the SLP and in the classroom and resulted in better-contextualised science teaching and learning. The same contextualisation did not take place in the Limpopo province.

■ Conclusion

As a research lens, CHAT can provide the researcher with deeper insights into the data, and into the complexity of the 'object' in an activity system, which can be achieved by looking at 'rules', 'division of labour' and 'tools' more closely. In this way, both external and internal factors that impact the 'object' of the activity system are exposed. In addition, CHAT as a lens has predictive value. If this SLP were to be offered in KwaZulu-Natal, the insights obtained from the Limpopo and Northern Cape interventions could assist the facilitators in circumventing these pitfalls.

In summary, CHAT can be a useful lens for researchers in different contexts (including other countries) to compare their work, showing how multiple perspectives can benefit educational transformation globally. What we have illustrated in this research in two provinces in South Africa can be applied in various international contexts.

The authors use CHAT as a research lens in several other chapters in this book to analyse their data. The purpose of this chapter was to provide the reader with a more nuanced understanding of the affordances of CHAT as a research lens.

Summary

This chapter highlights the use of third-generation CHAT as a research lens in education to study the affordances of IK in an attempt to contextualise the school science curriculum. Cultural-Historical Activity Theory is a flexible meta-theoretical framework that can assist the researcher in interpreting data from complex settings or activity systems, and to distil the finer nuances from the data. In this chapter, the authors reflect on a funded research project on the professional development of science teachers to illustrate the utility value of CHAT. This DBR focuses on teachers' participation in a SLP on IK and the transfer of the resultant knowledge to the school classroom. Teachers' experiences of such epistemological border-crossing (infusing IK into science curriculum themes) are explored. The SLP builds on the central wisdom of a Vygotskyan principle, namely, that learning leads to development. During the SLP, the teachers set personal development (learning) goals for themselves. The SLP was designed to enhance SDL. This chapter compares the findings from two SLPs. The first SLP took place in the Limpopo province (Cycle 1 of the DBR), and the second in the Northern Cape province (Cycle 2 of the DBR). The latter proved far more successful, and CHAT is used as a lens to shed light on contextual factors that may have contributed to the different outcomes. Much has been written about the 'object' in activity systems, but less has been written about the other components of third-generation CHAT. This chapter contributes to CHAT literature by

focussing on the ‘rules’, ‘tools’ and ‘division of labour’ as nodes in the activity system, and how they impact on the activity system’s ‘object’. A particular contribution of this chapter is an overview of the predictive value of CHAT as a research lens, specifically when researching the role of IK in better contextualising a predominantly Western school curriculum.

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Chapter 4

The affordances of indigenous knowledge in decolonising the curriculum, within a self-directed learning framework

Josef de Beer
Research Unit Self-Directed Learning, Faculty of Education, North-West University, Potchefstroom, South Africa

Elsa Mentz
Research Unit Self-Directed Learning, Faculty of Education, North-West University, Potchefstroom, South Africa

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Introduction: Our take on the decolonisation of the curriculum debate

Since the student protests of 2015, which almost paralysed tertiary institutions in South Africa, there has been a robust debate on the decolonisation of the curriculum. Arguments are characterised by two predominant frameworks, namely, Humanitarian arguments that forefront inclusivity or political arguments against what Mbembe (2016:32) calls a Eurocentric epistemological canon (refer to Le Grange's insights in Ch. 1). However, for over two decades, the dominance of Western epistemologies in African education has been criticised, and the student protests merely brought it to the attention of a wider audience (Seehawer 2018). The Kenyan scholar Wa Thiong'o (1986) is probably best known for his notion of the 'colonisation of the mind' – the eventual outcome of a school curriculum that marginalises African knowledge in a quest to canonise Western epistemologies.

In a young democracy, such as in South Africa, it is important that attention is given to the insights of scholars such as Wa Thiong'o and others. No one would argue against the need for redress in education in South Africa. We are probably lagging behind countries such as Canada, where the Education Renewal Initiative is a classic example of how the Canadian government worked with First Nations peoples to improve the quality of education in Canada (Battiste 2002). However, South Africa needs to be globally competitive, and we argue that 'Western science' concepts will always be at the core of curriculum content. Later in this introduction, we introduce the concept of 'glocalisation' (Patel & Lynch 2013), and we explore the affordances of epistemological border-crossing between Western science and IK.

Scholars such as Breidlid and Botha (2015:319–320) view IK as 'a counterhegemonic cultural force to that of colonialism'. These authors (Breidlid & Botha 2015:319–320) are of the opinion that IK is 'well-suited to exposing the Eurocentric assumptions inherent in conventional ideas about knowledge-making, and formal education, in particular'. Battiste (2002) agrees, stating that:

> Eurocentric thought asserts that only Europeans can progress and that indigenous peoples are frozen in time, guided by knowledge systems that reinforce the past and do not look towards the future. As a concept, indigenous knowledge benchmarks the limitations of Eurocentric theory – its methodology, evidence and conclusions – and reconceptualizes the resilience and self-reliance of indigenous knowledge. Knowledge is not a commodity that can be possessed or controlled by educational institutions, but it is a living process to be absorbed and understood. (pp. 4–5)

Much of the decolonisation of the curriculum debate focuses on 'a constructive integration of both indigenous and Western knowledges in education' (Seehawer 2018:94). In this chapter, we also advocate for an integration of indigenous and Western knowledges and adoption of African perspectives in teaching and learning. However, we do it from a learning psychology perspective (as opposed to the political slant introduced above), and we base our arguments on recent advances in neuroscience. In Chapter 4, the inclusion of IK is argued from an embodied, situated and distributed cognition perspective (Hardy-Vallée & Payette 2008), and we will not belabour these aspects here. Our central argument in this chapter, which we will illustrate with research data, is that the holders of IK often are (by definition) self-directed learners. Battiste (2002:5) claims that 'indigenous pedagogy values a person's ability to learn independently by observing, listening and participating with minimum intervention or instruction'. The IK holder's learning is directed by finding innovative solutions to authentic problems. This, we argue, holds lessons for formal school education. The ultimate goal of any educational system should be to train self-directed lifelong learners. Therefore, teaching students to appreciate and guide their own learning is of critical importance (Dubinsky et al. 2013).

Neuroscience research highlights the plasticity of the brain, and that experiences change the nervous system (owing to the strengthening of neuron synapses that accompany problem-solving). Unfortunately, as we show later in this chapter, many science classrooms today are characterised by teacher-centred ‘chalk-and-talk’ approaches, and ‘teaching-to-the-test’ (Ramnarain 2014), which do not challenge the learners and might not strengthen such neuron synapses. By identifying best practices, for example, authentic problem-solving in IK contexts, and applying them to formal science education, we might see an improvement in this sector.

Patel and Lynch (2013:223) speak of ‘glocalisation’ as ‘the merger of global and local perspectives on the socio-economic and political impact of all phenomena that affects local and global communities’. These authors unpack glocalisation in terms of education, and they describe glocalised teaching and learning as ‘curriculum considerations and pedagogical framing of local and global community connectedness in relation to social responsibility, justice and sustainability’ (Patel & Lynch 2013:223). The border-crossing we advocate in this chapter could package the universal truths that characterise Western science within a context of local relevance. In a world that is characterised by changing demographics, and increased student diversity in the classroom, South Africa can offer valuable perspectives on how IK could promote glocalised education.

■ What is self-directed learning?

Although the concept of SDL can be found in the work of Aristotle, Plato and Socrates (Carson 2012), the term emanates from andragogy or adult education theory. The classic definition of SDL given by Knowles (1975) reads as follows:

> [*P*]rocess in which individuals take the initiative, with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources, choosing and implementing appropriate learning strategies and evaluating learning outcomes. (p. 18)

Long (2000) distinguishes between four conceptualisations of SDL:

1. the sociological concept
2. the technique concept

3. the methodological concept
4. the psychological concept.

The sociological concept focuses on the individual learner within an adult education context. The technique concept focuses on the importance of group learning and social interaction within an adult education context. The methodological concept focuses on distance education processes and the opportunities they hold for SDL. According to Long (2000:16), 'successful self-direction in learning among the first three conceptualisations is not probable, and likely not possible, without the psychological processes that foster self-direction in cognition'. In this regard, Long (2000) identifies three primary dimensions (motivation, metacognition and self-regulation) and four secondary dimensions (choice, competence, control and confidence) as important psychological concepts needed to understand and foster SDL. Long's (2000) conceptualisations are also found in more recent definitions of SDL. Garrison (1997) defines:

> SDL as an approach where learners are *motivated* to assume personal responsibility and collaborative *control* of the cognitive and contextual processes in constructing and confirming meaningful and worthwhile learning outcomes. (p. 18)

Self-directed learning is, however, not exclusive to adult education (Candy 1991). Even small children exhibit characteristics of self-directed learners in the way in which they explore the world around them. Furthermore, Williamson (2007) and Leach (2000) are of the opinion that self-direction forms the basis of both formal and informal learning. This opinion is extremely important within the context of this chapter, where the informal learning of IK holders is investigated.

The effectiveness of learning depends on an individual's intrinsic motivation to learn (Long 2000), whereas flexible thinking also plays an important role (Gencel & Saracaloğlu 2018). Self-directed learners take responsibility and control of their own learning because of their internal drive to learn more. In the case of the holders of IK, the drive is often based on a fight for survival. Thus, self-directed learners take deliberate actions, using metacognitive processes, to direct their own learning (Breed 2013).

The SDL process starts with a need to know or a problem to be solved, from where specific learning goals are formulated – the stronger the desire to satisfy the need, the higher the motivation to self-direct learning. The SDL process further specifies that the learners identify available resources for learning, select their own strategies to reach the goal and evaluate if the learning need has been satisfied after completing the process (Knowles 1975). If not, the process starts all over again with new or adjusted goals, resources and/or strategies. The choice to select resources and strategies, and control their own learning, is part of this process.

This self-directed process explained above does not negate the fact that knowledge is socially constructed (Chang 2018). Thus, researchers in SDL acknowledge the fact that self-directed learners are not necessarily working individually. In fact, the most successful learning environments for the fostering of SDL include some form of collaborative learning (Amandu, Muliira & Fronda 2013). Self-directed learning is, therefore, characterised by a process of constructing meaning while sharing with others (Dawson et al. 2012).

Although most researchers working in the field of SDL acknowledge that SDL can be seen as a process, there are others who also view SDL as a personal characteristic applied within a specific context. We concur with Hiemstra and Brockett (2012) that process, context and personal qualities are important aspects of SDL and that they are interconnected.

Self-directed learning can best be fostered in a formal learning context through active learning strategies such as PBL and CL (context) provided that a real-life, challenging problem is posed (Van Zyl & Mentz 2015). A highly self-directed learner is capable of performing the process explained by Knowles effectively and will display characteristics such as a love for learning, curiosity, critical thinking, self-efficacy and an intrinsic motivation to learn more, to name a few SDL characteristics (Guglielmino 2013). Self-directed learners have the freedom to make choices and to decide how to direct their own learning.

For the purpose of the discussion in this chapter, we will use Knowles's (1975) definition and Long's (2000) conceptualisation of SDL.

What is indigenous knowledge, and why is it important in a self-directed learning context?

Indigenous knowledge is described by Battiste (2002) as:

> [*A*] complex set of technologies developed and sustained by indigenous civilizations. Often oral and symbolic, it is transmitted through the structure of indigenous languages and is passed on to the next generation through modelling, practice and animation, rather than through the written word. (p. 2)

Rankoana (2017:63) describes 'indigenous knowledge as a systematic body of knowledge acquired by local people through the accumulation of experience, informal experiment, and understanding of their environment'. Jones and Hunter (2003, cited in De Beer 2015:5) and Michie (2000, cited in De Beer 2015:5) listed a number of characteristics of IK, which are relevant in this context:

- IK is based on experience
- often tested over centuries of use
- developed as a collective database of observable knowledge
- adapted to local culture and environment
- dynamic and changing: a living knowledge base
- application to problem-solving
- oral transmission, sometimes encapsulated in metaphor
- not possible to separate IK from ethics, spirituality, metaphysics, ceremony and social order
- bridging the science of theory with the science of practice
- a holistic (IK) versus a reductionist (Western science) approach
- an ecologically-based approach
- contextualised versus decontextualised science.

In these IK (informal) learning environments, a context is created that promotes SDL, as we will show later in this chapter.

Methods

This chapter attempts to answer two research questions:

- What research data support the hypothesis that the holders of IK are self-directed learners?
- How can formal science education benefit from insights into learning in informal, IK contexts?

One of the authors (De Beer) coined the construct EKI together with Van Wyk (De Beer & Van Wyk 2011) as part of these authors' Matrix Method for ethnobotanical research. In this chapter, the authors (De Beer & Mentz) look at the EKI values of Khoi-san and Venda people through a different lens, namely, that of SDL, in an attempt to distil insights that could benefit science education in South Africa. Cultural-Historical Activity Theory (Engeström 2009) is used to compare informal learning (in IK contexts) and formal science education.

In this chapter, reference is made to individuals who are holders of IK. Their names are disclosed with their written consent, as they take pride in their IK. The focus in this chapter is on their *learning* and not on their plant knowledge per se. An account of their ethnobotanical knowledge has been published by De Beer and Van Wyk (2011). The said publication serves to protect the intellectual property rights of these knowledge holders and to prevent any pharmaceutical company from potentially claiming the rights to this knowledge in the future. Ethical clearance for the EKI work was obtained from the University of Johannesburg. Ethical clearance for the IK research in a science education context was obtained from NWU. Furthermore, the researchers subscribe to the Code of Ethics of the International Society of Ethnobiology.

The holders of indigenous knowledge as self-directed learners

De Beer and Mentz (2016, 2017) claim that the holders of IK are often self-directed learners. In the sections that follow, we provide justification for this claim, by analysing data using the insights of authors such as Knowles (1975), Guglielmino (1978) and Long (2000) on SDL. We start with data on learning about useful plants in cultural settings and then continue with a focus on SDL within an ethno-veterinary context.

Self-directed learning and authentic problem-solving: Ethnobotanical Knowledge Index

Brookfield (1993) is of the opinion that SDL often has political roots, as issues of power and control are often catalysts for SDL. Often, the holders of IK live in impoverished socio-economic conditions, and their SDL is focussed on developing skills that will ensure a better quality of life (Andruske 2000). One example of such SDL, propelled by the drive to ensure a better life, is the case of women in British Columbia who, through SDL, equipped themselves for formal employment in order to free themselves from their dependency on welfare (Andruske 2000). This is also true of many of the descendants of the Khoi-san in the Northern Cape (De Beer 2012). The Khoi-san participants who were involved in the ethnobotanical study of De Beer (2012) were predominantly farm labourers, and many of them were illiterate. Because of a lack of material resources and the physical isolation of the farms, many of these farmworkers are holders of a rich IK on useful plants (both edible and medicinal). As these farmworkers do not have easy access to Western medicines, they use traditional medicines from nature. Their extensive knowledge of edible and medicinal plants improves the quality of their lives, as they have free access to natural resources from their environment.

The fact that most of the participants were illiterate proves that the knowledge was not acquired from books but was orally transmitted across generations. However, this is a living knowledge base, and the holders of IK have to continuously solve new problems. One such example was finding a treatment for the HIV and AIDS pandemic. Very soon – through experimentation and careful observations – holders of IK (e.g. traditional healers) discovered that the 'Cancer Bush' or 'Kalkoenbos' (*Sutherlandia frutescens*) (Figure 4.1) was effective in building a patient's immune system (Van Wyk, Van Oudtshoorn & Gericke 2009). Similar to the processes followed by Western scientists, the holders of IK make careful observations, formulate hypotheses, choose suitable experimental designs and test plant medicines *in vivo*.

De Beer and Van Wyk (2011:743) developed an EKI. This index provides a unique insight into SDL in informal settings. The EKI is a tool that forms part of these authors' Matrix Method, a rigorous practical method that allows rapid quantification of the ethnobotanical knowledge of participants. The participants in this study – all descendants of the Khoi-san people of different ages – were shown a collection of 64 herbarium voucher specimens of predominant plants in the Agter-Hantam area.

Source: Photograph taken by Josef de Beer, exact date and location unknown, published with permission from Josef de Beer.

FIGURE 4.1: The Cancer Bush, *Sutherlandia frutescens*, serves as an example that IK is not static, but that it evolves in order to solve authentic problems that face communities.

During personal interviews with each participant, their knowledge was recorded. A simple questionnaire with three questions was used (De Beer & Van Wyk 2011):

1. Does the person know or recognise the plant?
2. Does the person have a name for the plant?
3. Can the person name any uses of the plant (e.g. as food, medicinal use or for arts and crafts)? (p. 743)

For the answer to each question, a numerical value was allocated (1, 2 or 3). The last digit (Table 4.1) represents the sum of the three values (the maximum value being 6) (De Beer & Van Wyk 2011:743). The EKI expresses the participant's knowledge about useful plants. The EKI is obtained by multiplying the total number of plants (64) with the score obtained by the participant for each species (with a maximum score of 6), divided by 384 (obtained by multiplying 64 plants with the maximum score of 6 per species) in the case of the Agter-Hantam data. This is followed by EKI findings from two other regions, namely, Namaqua/Kamiesberg (Nortjé 2011) and Vhavenda (Magwede, pers. comm., 2018), to ascertain if the latter findings support those from the Agter-Hantam.

❑ The Ethnobotanical Knowledge Index of participants in the Agter-Hantam

Table 4.1 provides a simplified excerpt from the Matrix of De Beer and Van Wyk (2011:750), indicating the EKI of selected participants in their study.

There is an interesting pattern in the EKI's of the different participants. Gert and Andreas, two young boys, had the lowest EKI (both a value of 0.27). The older boys, Bertus and Frans, had slightly higher EKI values (0.37 and 0.38, respectively). The adults, Christien and Jan, had high EKI values of 0.82 and 0.93, respectively.

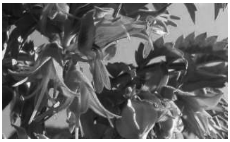
Closer inspection of these values indicates that the young boys, Gert and Andreas, were relatively knowledgeable about the edible plants, such as the Snotwortel (*Grielum humifusum*), Jakkalskos (*Hydnora africana*), the Bokhorinkie (*Microloma sagittatum*),

TABLE 4.1: Simplified excerpt from the Matrix of De Beer and Van Wyk (2011:750), indicating the EKI of selected participants.

Plant	Photo	Young children		Older children		Adults	
		Gert	Andreas	Bertus	Frans[a]	Jan	Christien
Grielum humifusum (Snotwortel)		1236	0000	0000	1236	1236	1236
Hydnora africana (Jakkalskos; Kannikan)		1001	1001	1236	1236	1236	1236
Microloma sagittatum (Bokhorinkie)		1236	1236	1236	1236	1236	1236
Quaqua incarnata (Karoena)		1236	1203	1203	1236	1236	1236
Aloe microstigma (Veldaalwyn)		1236	1236	1236	1236	1236	1236
Artemisia afra (Wilde-als)		0000	0000	1236	1203	1236	1236

Table 4.1 continues on the next page →

TABLE 4.1 (Continues...): Simplified excerpt from the Matrix of De Beer and Van Wyk (2011:750), indicating the EKI of selected participants.

Plant	Photo	Young children		Older children		Adults	
		Gert	**Andreas**	**Bertus**	**Frans[a]**	**Jan**	**Christien**
Mentha longifolia (Balderjan; Ballerja)		0000	0000	1236	1203	1236	1236
Ballota africana (Kattekruid)		0000	0000	0000	0000	1236	1236
Melianthus comosus (Kriekiebos)		0000	0000	0000	0000	1236	1236
Dicoma capensis (Karmedik; Hen-en-kuikens)		0000	0000	0000	0000	1236	1236
EKI		**0.27**	**0.27**	**0.37**	**0.38**	**0.93**	**0.82**

Source: Adapted from De Beer (2012).
Note: Only 10 of the 64 plants are included by way of example.
[a]Frans was interviewed in a subsequent survey.

Karoena (*Quaqua incarnata*) and the Veldaalwyn (*Aloe microstigma*). The Veldaalwyn (*Aloe microstigma*) leaves are dried and eaten as an energy booster, but it also has a medicinal value (as a medicine to treat stomach ailments and to relieve back pain). Given the fact that these boys live in poor socio-economic circumstances, it becomes clear that a workable knowledge of the edible plants of the region probably provides a welcome relief from hunger. Their knowledge of plants is needs-driven. As they were of relatively good health, they do not *need* to know much about medicinal plants – both boys were ignorant about medicinal plants in the area, such as Wilde-als (*Artemisia afra*), Ballerja (*Mentha longifolia*), Kattekruid (*Ballota africana*), Kriekiebos (*Melianthus comosus*) and Karmedik (*Dicoma capensis*).

The older boys, Bertus and Frans, also had knowledge of two of the common medicinal plants used in the Agter-Hantam area, namely, Wilde-als and Ballerja. *Artemisia afra* (Wilde-als) and *Mentha longifolia* (Ballerja) are important medicines for common cold and flu (influenza), conditions not restricted to any particular age group. Therefore, it makes sense for these boys – who themselves could experience common cold and flu, to know about these veld medicines. However, they were ignorant about the uses of other medicinal plants, such as Kattekruid, Kriekiebos and Karmedik, as these plants are used to treat conditions that occur in older people.

Ballota africana (Kattekruid) is used by women after childbirth and to stimulate milk production in lactating women (De Beer 2012). *Melianthus comosus* (Kriekiebos) is used to treat rheumatic joints and backache – conditions that are a result of hard physical labour required of farmworkers. *Dicoma capensis* (Karmedik) is also used to treat high blood pressure, back pains and cancer (De Beer 2012). It makes sense, therefore, that children do not have knowledge of these plants, as they are not of much relevance to their daily needs. For older people, these medicinal plants can bring relief from ailments common to their age group and thereby improve their quality of life.

These EKI values, and other data from the interviews, show that SDL takes place. It starts with a *need* that is identified. Children need to identify edible plants, learn where to find these plants and how to harvest them sustainably. As children grow older and contract common cold and flu, there is a need to know about certain medicinal plants. For ageing adults, there is a need to treat conditions such as rheumatism, and this explains their wider knowledge of medicinal plants and higher EKI values. Plants are chosen after consulting the elders, as well as experimenting with existing plants in their environment. They were most probably witness to how specific plant material was prepared for medicinal use. Their learning was not dependent on memorisation of facts that have no meaning. The former context is when metacognitive processes play an important role.

It is also worth noting that such learning occurs in a social structure. Both PBL and CL – approaches that can potentially enhance SDL – are used. A knowledgeable elder, such as Jan Baadjies, can assist in scaffolding learning about useful plants for members of the community. Learning entails more than simply identifying the plant species. The learner also needs to understand the physiological needs of the plant, as this will determine the habitat in which it will grow. This is crucial to the speedy location of plants. Also, harvesting is to be done sustainably. Through experimentation, best practices are identified, for example, whether the leaves or roots are most efficacious, which promotes sustainable harvesting practices.

If one now looks at this informal learning through the lens of Knowles's (1975) definition of SDL, it becomes clear that holders of IK are often self-directed learners. The community members have identified a need, that is, because they live in poor socio-economic conditions, they need to have sufficient knowledge of edible and medicinal plants in their environment to improve the quality of their lives. Thus, they have identified their own learning needs. For young children, they predominantly need to learn about edible plants. For older people, the learning need would mean a good knowledge of medicinal plants:

- Learners identify resources for learning to address their learning goals. As IK is an oral tradition, these resources might be knowledgeable community members or own experiences and observations.
- Appropriate learning strategies are adopted. These could include field trips with knowledgeable mentors, experimentation (including the formulation of hypotheses, careful observation, data collection and drawing conclusions) and CL strategies through discussions with others who share the same needs. Experimentation could include different preparation methods and dosages (mixtures, ointments, snuffs, enemas, etc.) and

reflection on previous experiences, which form part of the metacognitive processes involved.
- Outcomes are evaluated by determining whether the learning need was addressed. Could edible or medicinal plants be harvested to fulfil a specific need? Metacognition and reflection also form an important part of this step of the process.

Ethnobotanical Knowledge Index values in the Kamiesberg, Namaqualand

Nortjé (2011) conducted a similar study in the Kamiesberg region to that of De Beer (2012). She also used the Matrix Method and interviewed people on the use of 85 plant species. However, a big difference was that she focussed exclusively on the use of medicinal plants and not edible plants. However, several of the 85 medicinal plants identified in her study are also edible; the authors of this chapter focussed on children's recognition of edible and non-edible medicinal plants. Her data show a similar pattern to that of De Beer (2012) for the Agter-Hantam area (Table 4.2).

Firstly, a similar pattern is displayed in both the Kamiesberg and the Agter-Hantam, with children having lower EKI values than adults. Nortjé (p. 128) explains the lower EKI's of children in the Kamiesberg (0.17 as compared to 0.26 in the Agter-Hantam) in terms of the fact that her survey focussed only on the medicinal plants and not on edible plants. A secondary analysis of her data shows that children performed significantly better in recognising

TABLE 4.2: Average EKI of participants in the Kamiesberg (Nortjé 2011:128) as compared to data from the Agter-Hantam.

Age groups	Kamiesberg				Agter-Hantam			
	R	N	M	EKI	R	N	M	EKI
Senior citizens (age 55+)	0.74	0.64	0.43	0.55	0.76	0.66	0.38	0.54
Adults (age 20–54)	0.74	0.62	0.38	0.52	0.87	0.75	0.36	0.58
Children	0.60	0.20	0.04	0.17	0.43	0.33	0.15	0.26

Source: The authors' interpretation of data found in Nortjé (2011:128).
R = recognition; N = plant naming; M = providing medicinal uses of plants; EKI = Ethnobotanical Knowledge Index averages.

and identifying those (medicinal) plants that are also edible, such as *Carpobrotus edulis* (Suurvy or Ghaukum), *Conicosia elongata* (Varkiesknol), *Hoodia gordonii* (the 'Ghaap') and *Aloe microstigma* (Veldaalwyn), which is eaten as an energy booster, and *Viscum capense* (Lidjiestee), which is commonly used as a health tea. Children commonly eat *C. edulis* as a snack – they suck the sweet–sour pulp from the ripe fruit (Van Wyk & Gericke 2018).

Had Nortjé asked children to provide uses other than medicinal, the EKI values of the Kamiesberg would probably have matched those of the Agter-Hantam. For example, all the children in her survey could recognise *C. edulis*, and they could also name the plant. This provided a score of 3 out of the possible 6. During the interviews, she asked children if they knew of any medicinal uses of *Carpobrotus*, which they did not. However, if she asked them to name any uses (including that of being a food source), the EKI values would probably have been higher.

Again, the data show that young children's primary interest is learning about edible plants, as this relates to an authentic problem they face (insufficient food) and, thus, an identified learning goal. Only later in life, do they show interest in medicinal plants.

Ethnobotanical Knowledge Index values in Vhavenda

Magwede and Van Wyk (2018) conducted an ethnobotanical inventory of useful plants of the Vhavenda people in the Vhembe district of the Limpopo province. The Matrix Method was used, and participants were shown a flip-file with 327 plant species. Magwede and Van Wyk included food plants as a category, as well as medicinal plant use. Senior citizens had the highest average EKI value (0.6), followed by adults (0.52) and children with the lowest (0.33). Again, children could, in most cases, only identify edible plants and were not knowledgeable about medicinal plants (Magwede, pers. comm., 2018). Various species of *Amaranthus* were well known to all the children, as this genus includes popular vegetables (such as Vowa, Vowakholomo, Marog or Misbredie) (Magwede et al. 2018). Children were also very knowledgeable about edible fruits, such as *Hoslundia opposite* (Tshivhuvhudzi or Butter Berry) and *Vitex ferruginea* (Mupfuluphumbu). As would be expected, children mentioned the use of *V. ferruginea* as a food source, but did not comment on its medicinal use for sore throats.

Our data indicate a needs-driven learning trend, characterised by authentic problem-solving. From these indigenous (informal) learning settings, we conclude this chapter by focussing on the lessons these hold for formal education in South Africa. Before we conclude, we use a second example to show that the holders of IK are self-directed learners.

Subsistence livestock farmers in the Vhembe district in Limpopo and in the Eastern Cape province as self-directed learners: Combating ticks

In both the Vhembe district in Limpopo and in the Eastern Cape province, there are many subsistence livestock farmers that live and work in marginalised communities, characterised by poor socio-economic conditions. These farmers are dependent on healthy livestock to survive, but they often do not have the financial resources to buy expensive veterinary medicines. In order to solve this problem, they demonstrate SDL, as is described in the following sections.

Diagnosing own learning needs: The need to find sustainable solutions to the problem of ticks

Ticks negatively affect the health of animals and can lower production, which is detrimental to the subsistence farmer. Ticks transmit a wide range of pathogens that include protozoa, bacteria and viruses. Examples of such diseases are tick-borne relapsing fever, Babesiosis and African tick-bite fever (Chitanga, Gaff & Mukaratirwa 2014). Subsistence farmers cannot always afford expensive commercial veterinary medicines. In addition, many farmers realise that some of these medicines are no longer very effective as pathogens develop resistance to antibiotic over time (Magwede et al. 2014).

On the other hand, ethno-veterinary plants inhibit bacteria using mechanisms that differ from those of commercial antibiotics (Magwede et al. 2014). Subsistence farmers and holders of IK, as self-directed learners, have identified a learning need, namely, to solve this real-life problem and to find cost-effective treatments to control ticks in cattle herds.

Identifying human and material resources for learning

As in most IK contexts, learners have to identify knowledgeable others in the community. As IK predominantly relies on an oral tradition, there is often a shortage of printed resources. Knowledge of effective tick control is mostly self-taught through time spent in the veld, as well as through apprenticeships with experts – local holders of IK. Knowledge is also shared during clan gatherings (Constant & Tshisikhawe 2018). Plants such as *Lantana camara*, *Synadenium cupulare* and *Cissus quadrangularis* are used to control ticks, as well as old engine oil and Jeyes fluid (Magwede et al. 2014; Moyo et al. 2009). It is rather problematic that most rural farmers start to consider ticks as problematic only when cattle develop wounds caused by a heavy infestation of ticks (Magwede et al. 2014). It is only at this stage that the farmer starts experimenting with plants to heal the wounds. Topical application of plant materials as a paste or sap is a common practice. Decoctions are also made. These are administered orally when cattle are in the kraal (Magwede et al. 2014). The holders of IK are aware that these plant medicines should be harvested sustainably using the leaves and stems of *Synadenium cupulare* (Dead-man’s tree) to make an ointment for wounds, rather than harvesting the roots (Magwede et al. 2014).

Choosing and implementing appropriate learning strategies

Cooperative learning is prominent in IK settings (Jautse, Thambe & De Beer 2016). Also, Vhembe boys learn from the more knowledgeable others in community, going out with elders to collect ethno-veterinary plants (Magwede et al. 2014). Rankoana (2017) indicates that informal experimentation is also common. Through experimentation and observation, subsistence farmers have noticed that some of the plants used to combat ticks have a stronger effect when mixed with conventional acaricides (commercial tick-repellents). For instance, in the Vhembe district, the bark of *Philenoptera violacea* (Apple-leaf) has a stronger effect when mixed in a decoction with an acaricide (Magwede et al. 2014). Through experimentation and careful observations, IK holders have discovered the synergistic effect of the mixed medications.

Most of the tick-repellent plant extracts were discovered in the process of treating tick-infected cattle wounds. Indigenous knowledge holders would have observed a reduction in tick numbers after the topical application or oral administration of certain plant extracts (Magwede et al. 2014:163). This would have led to further experimentation.

Evaluating learning outcomes

Each intervention is followed by some assessment. Was this an effective measure to combat ticks? Different subsistence farmers would share their experiences in using specific ethno-veterinary plants. Reflections would consider the collection of plant material (whether roots, stems or leaves are used), methods of preparation (infusions, lotions or ointments) and methods of administration (orally by addition to drinking water or topically by application to the skin or nasal passages). Where a plant extract does not provide the desired effect in combating ticks, it is mixed with other acaricides, and the synergistic effect thereof is monitored (Magwede et al. 2014). One example is the use of a decoction prepared from the bark of *Philenoptera violacea* (Mufhanda or Apple-leaf) and a conventional acaricide to strengthen its effect (Magwede et al. 2014). Again, metacognitive and reflective skills play an important role in this process.

In the close-knit rural societies where the subsistence farmers live and work, they learn about best practices during clan gatherings (Constant & Tshisikhawe 2018). This indicates thoughtful reflection. As the farmers share best practices, they come to distinguish between effective and non-effective measures.

Western science is giving credibility to this IK. Laboratory tests have shown that Jeyes fluid and engine oil (an indigenous remedy for ticks) have an efficacy almost equivalent to that of Ektoban (a commercial acaricide). A plant extract such as *Lantana camara* has an efficacy of 57% (Moyo et al. 2009). Traditional knowledge on combating tick-borne diseases may, therefore, enrich modern pharmacology (Kioko et al. 2015).

Lessons from indigenous knowledge holders for formal science education

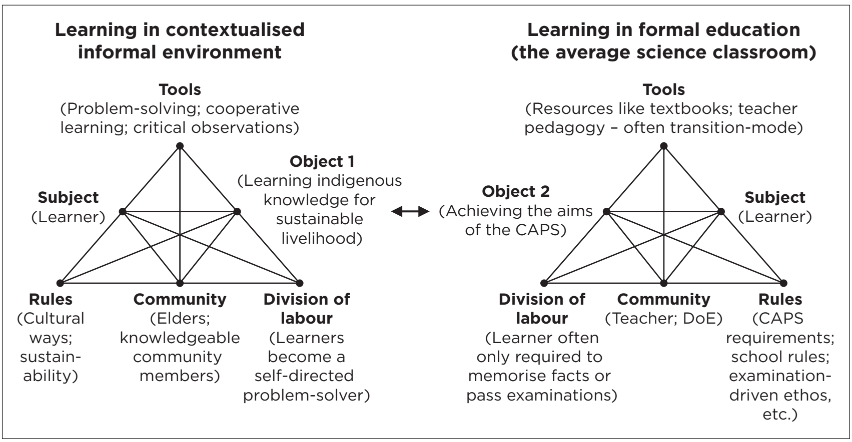
The above examples of the EKI and combating ticks in ethno-veterinary contexts hold important lessons for science education in South Africa. Webb (2017:119) describes the general pattern of teaching and learning in science classrooms in South Africa as ‘traditional teaching methods exemplified by chorus teaching, repetition, memorisation and recall’. Such methods do not promote SDL and do not adequately prepare learners for a complex 21st century. In contrast to this scenario, the above examples illustrate how holders of IK engaged in PBL, encouraged by a ‘driving question’ that is rooted in an authentic problem or situation. In this regard, there is synergy between SDL and IK, as both place a high premium on PBL and CL and on skills development for sustainable living.

In Chapter 3, we focussed on CHAT as a research lens. In Figure 3.4 in Chapter 3, we showed the alignment between the

SDL process (activity system on the left) and IK (activity system on the right). The 'subjects' of the two activity systems – SDL and IKS, respectively – shared a common 'object', namely, the development of skills and acquisition of knowledge to succeed in society (make a living). Among the 'tools', there were also similarities, namely, an emphasis on cooperative and PBL. We, therefore, conclude that, by distilling principles that characterise learning in IK contexts, we might enhance SDL in the formal classroom.

In formal science education, we tend to provide answers to questions that students have not asked for themselves. In the IK examples provided earlier, learners were motivated to address authentic problems. In the formal classroom, curriculum content is often disconnected from the everyday lives of the learners, which can result in disengaged learners.

In the next few paragraphs, we compare two activity systems, namely, a young learner in a rural area, learning informally from holders of IK (activity system A on the left in Figure 4.2), and a learner in a formal school classroom (activity system B on the right in Figure 4.2).



CAPS, Curriculum and Assessment Policy Statement; DoE, Department of Education.

FIGURE 4.2: Comparing informal learning in an IK context (left) with formal school learning (right).

Learning in a contextualised informal environment

In the activity system on the left, the learner (as 'subject') is faced with an authentic problem: either (as a herd boy) finding solutions to external parasites such as ticks on cattle or learning to identify and locate edible plants in order to not go to bed hungry. There is, therefore, an affective commitment to the identified learning goals. Resources are identified to achieve the 'object' of the activity (knowledge for sustainable livelihoods). In this regard, it is essential to focus on the 'rules' characterising the activity system. Jautse et al. (2016) have shown that the holders of IK often display a collective responsibility, which is very reminiscent of Johnson and Johnson's (1989) criteria for positive social interdependence in CL. Magwede et al. (2014) show that boys and young men in the Vhembe district are the major contributors to the collective knowledge of tick control in cattle. The elderly in the community are the major contributors of knowledge (Table 4.3), but boys and young men in the 15 – 25 year age group show a remarkably high contribution to knowledge.

Magwede et al. (2014) explain this as: young men in the 15 – 25-year age group are the collectors of medicinal plants. They escort elders during field work, and they assist with digging and collecting plants in places the elders find difficult to access. Important is the fact that these young men display a collective responsibility. For the subsistence farmers in the Vhembe district, livelihoods depend on healthy cattle, and these young men realise their responsibility, that is, to contribute to the

TABLE 4.3: Percentage contribution of different age groups to collective knowledge of tick control in the Vhembe district.

Gender	Age (years)							Total
	<15	**15–25**	**26–35**	**36–45**	**46–55**	**56–65**	**>65**	
Male	4.4	11.1	4.4	6.7	8.9	13.3	20	68.8
Female	0	4.4	0	2.2	2.2	8.9	13.5	31.2
Total	4.4	15.5	4.4	8.9	11.1	22.2	33.5	100

Source: Magwede et al. (2014:158)

knowledge base to ensure that cattle herds are healthy. An unspoken ‘rule’ in the activity system is therefore the collective responsibility for maintaining a living knowledge base.

Another prominent ‘rule’ in this activity system is that of environmental conservation and sustainable harvesting of ethno-veterinary plants. Magwede et al. (2014) interviewed 42 Vhembe holders of IK, and they indicated that one of the reasons why they desist from using commercial pesticides to combat ticks is an uncertainty about their side effects. They are very aware that microbes become resistant to popular antibiotics. They, therefore, continue to experiment with ethno-veterinary solutions to counter the problem of ticks.

‘Tools’ utilised include PBL and CL. The subsistence farmers have to find solutions when ethno-veterinary medicines do not provide the desired outcomes. For instance, certain farmers realised that a decoction prepared from *Philenoptera violacea* was not as effective as expected; however, through experimentation they came to realise that it was more effective when mixed with acaricide.

The ‘community’ consists of, among others, elders who have comprehensive knowledge. ‘Division of labour’ refers to the different roles of the learner, and here the learner as a self-directed problem-solver should be highlighted.

Learning in the formal science classroom

The ‘object’ in the second activity system, the formal school system, is characterised by what Mbembe (2016:31) calls ‘the mania for assessment’. Firstly, it should be noted that the school curriculum objectives are plausible and emphasise inquiry skills among others. The revised South African school science curriculum advocates for an approach that inspires ‘learners to explore objects, situations and events in their immediate environment, to collect data and record information and draw conclusions accurately’ (Department of Basic Education 2002:34). However, these goals are often not achieved owing to systemic problems such as packed curricula and time schedules (the ‘pace-setters’), which place pressure on teachers to 'complete content merely to comply with the pace setter rather than focus on learners' cognition' (Reddy, De Beer & Petersen 2018). Also, Ramnarain (2014:72) describes the unfortunate and common practice that 'teachers deliberately tailor their instruction according to expected test and examination questions'. According to Ramnarain (2014:72), it is especially teachers at township schools who 'perceive a didactic approach to be effective' if it prepares 'learners for tests and examinations'.

Instead of using 'tools' such as effective CL and PBL in the science classroom, many teachers fall back on transmission-mode teaching (such as the traditional lecture method). Ramnarain (2014:71) has shown that 'with regard to inquiry facilitation for conceptual understanding, teachers at township and rural schools believe their explanations of concepts to be more effective'. Research conducted by Ramnarain and Schuster (2014:627) has shown that teachers at township schools have a strong 'active direct' teaching orientation (Table 4.4 and Figure 4.3), and they would lecture to the learners; and, where practical work is done, these follow a recipe-like approach to confirm what has been dealt with in theory. On the other hand, these researchers have found that many 'teachers at suburban schools exhibit a guided inquiry orientation, with concepts being developed via a guided exploration phase' (Ramnarain & Schuster 2014:627).

The transmission-mode approaches often do not create inviting learning environments. Schulze and Van Heerden (2015) have shown that many South African school learning environments lack motivational value. These authors advocate that teachers should rethink their teaching methods and lesson activities, as 'the science classroom is the most significant factor in motivating students to achieve academically in science' (Schulze & Van Heerden 2015:7). In the formal school context, the 'community' is not very supportive in inspiring the learner to take the role of a 'scientific sleuth' and solve problems.

Unlike learners having to solve authentic problems in informal learning contexts and develop as self-directed learners, the practices in many schools inhibit both PBL and SDL.

TABLE 4.4: Pedagogical foci.

Fundamental epistemic mode	Variant for each mode	Operationalised description
'Ready-Made-Science'	1. Didactic direct	Teacher presents and explains science content directly and illustrates with example or demonstration. No student activities.
Science presented as factual knowledge	2. Active direct	Teacher presents and explains science content directly; students actively engage in verification and confirmation.
'Science-in-the-Making'	3. Guided inquiry	Students actively explore idea with teacher guidance
Science as developed by the process of scientific inquiry	4. Open inquiry	Students actively explore idea as they choose; teacher facilitates the process but does not describe.

Source: Cobern et al. (2014:2270).

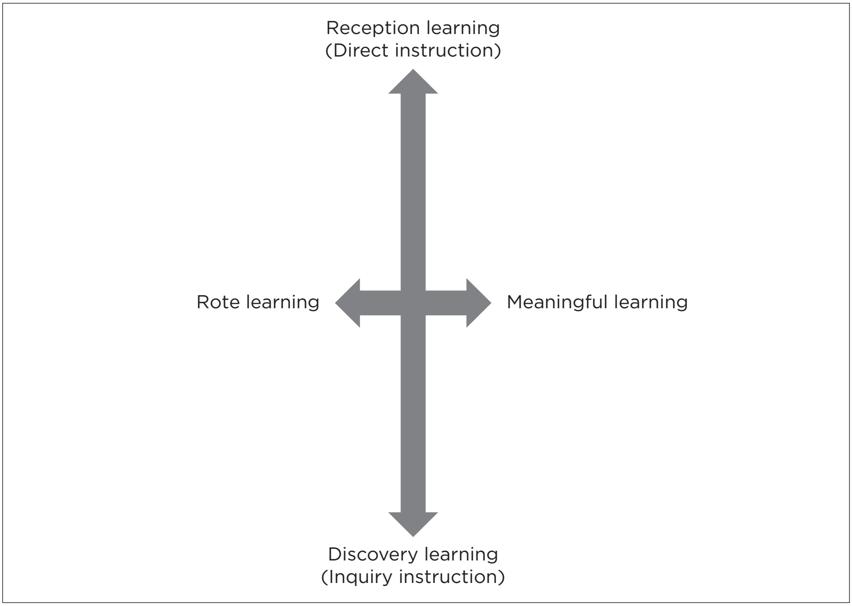


FIGURE 4.3: Ausubel's axes.

Contradiction of control

An activity system is built around its 'object' (Engeström, 2009). It is useful to distinguish between the *envisaged* (anticipated) object and the *realised* object. In the case of the formal science classroom (the activity system on the right in Figure 4.2), the envisaged object might be the ambitious CAPS curriculum aims (Department of Basic Education 2002:5).

The National Curriculum Statement Grades R-12 aims to produce learners that are able to:

- identify and solve problems and make decisions using critical and creative thinking
- work effectively as individuals and with others as members of a team
- organise and manage themselves and their activities responsibly and effectively
- collect, analyse, organise and critically evaluate information
- communicate effectively using visual, symbolic and/or language skills in various modes
- use science and technology effectively and critically showing responsibility towards the environment and the health of others
- demonstrate an understanding of the world as a set of related systems by recognising that problem-solving contexts do not exist in isolation.

The *realised* object is often, in many classrooms, something completely different, and the description by Ramnarain and Schuster (2014) is probably apt, that this emphasis:

> [*O*]n scoring high marks meant that these teachers, although they believed in the notion of student-centeredness, felt the need to adopt teaching methods whereby students would assimilate the 'products' of science, i.e. the body of acquired knowledge, and thus be better prepared for these examinations. (p. 648)

This 'teach towards the test' erodes elevated aims such as fostering critical and creative thinking and problem-solving skills.

McNeil (1999) coined the term 'contradiction of control'. This term sheds light on the complexity of the 'object' in the activity system. In this case, the intended 'object' is not necessarily achieved, owing to tensions in the activity system. For instance, the pace-setters could be seen as a 'rule' that negatively impact on 'tools' such as PBL, as many teachers hold the (erroneous) assumption that such inquiry approaches take more time than transmission-mode approaches. Furthermore, the teacher (part of the 'community') might not have the necessary skills to effectively facilitate inquiry (problem-based) approaches in the classroom, thus reverting to 'chalk-and-talk' approaches. Ramnarain and Schuster (2014) emphasise that facilitating scientific investigations in the science classroom:

> [*R*]equires a deep understanding of science practices and investigative skills, in order to guide students in formulating research questions and planning investigations, as well as a deep understanding of science concepts. (p. 648)

Because South Africa has many underqualified science teachers (Bernstein 2011), who do not possess the above competencies, many teachers depend on lecture-mode teaching. The 'division of labour' refers to the different roles of the 'subject' (learner). The teacher-centred, lecture-mode teaching and learning, that often characterises the science classroom, does not provide the learner with the opportunity to take on the role of a problem-solver or a novice scientist. Instead, the learner becomes a consumer of knowledge, regurgitating learnt facts in the examination. This prevents the development of a nuanced understanding of the nature and tenets of science (Cronje, De Beer & Ankiewicz 2015). This results in a 'contradiction of control', with a conflict between the envisaged and realised objects of the activity system.

In the case of the activity system on the left-hand side of Figure 4.2, namely, learning in a contextualised informal environment, there is no such 'contradiction of control'. The 'realised object' is the same as the 'envisaged object', namely, obtaining IK to ensure a sustainable livelihood.

Lessons for formal school education

Based on Ausubel's (1963) work on meaningful learning, Cobern et al. (2014:2270) developed the construct shown in Table 4.4 and Figure 4.3, indicating the pedagogical foci of teaching–learning activities superimposed on Ausubel's axes.

In the case of Vhembe learners engaging in PBL (experimenting with ethno-veterinary plants as acaricides), open discovery learning is clearly taking place (Table 4.4 and Figure 4.3). This is in stark contrast to many formal science classrooms where science is presented as factual knowledge ('ready-made science'), which does not provide learners with a good understanding of the tenets of the NOS. Neither does it speak to the affective domain in order to motivate learners. The informal learning taking place in IK contexts is often characterised by creative problem-solving, and the learner is motivated to solve an authentic problem.

All stakeholders in science education could benefit from these insights. A teacher should contextualise the learning content in a way that the learners are confronted with an authentic problem to be solved. In this regard, the teacher could structure the learning task around the six key features of project-based environments as identified by Krajcik and Shin (2016:276):

- There should be a driving question, a problem to be solved.
- There should be a focus on key standards in science (in a South African context, the CAPS specific aims).
- Learners should explore the driving question by participating in scientific practices.
- Learners should engage in collaborative activities to find solutions.
- In the process, learners should be scaffolded (e.g. with learning technologies).
- Learners should create tangible products or artefacts as representations of learning.

If we examine the learning of Vhembe children according to these features, it becomes clear that they attain the grade. The driving question, 'how can we ensure that our cattle are healthy and tick-free?', provides the stimulus for them to learn about ethno-veterinary plants from elders, to experiment with various combinations of acaricides to determine their synergistic effects, and to make careful observations. This they do in a CL environment, and it results in tangible products (ethno-veterinary acaricides) that are made available to other people in the community.

In conclusion, the formal science curriculum in South Africa advocates for the inclusion of IK as one of the principles that should underpin education (Department of Basic Education 2011:5). The curriculum also anticipates the development of creative thinking and problem-solving among learners. Bybee (1993) and Ramnarain and Schuster (2014:629) highlight the 'pivotal role of the teacher in curriculum implementation' and warn that, if teachers' practices do not represent these curriculum innovations, the entire process of curriculum change fails. It is, therefore, essential that teacher training should also address these insights from the holders of IK – in both pre- and in-service teacher education – in order to bring these curriculum goals to fruition. In Chapter 2, the authors reflected on in-service teacher education programmes offered by NWU that build on these insights. These programmes guide teachers on how epistemological border-crossing between IK and Western science (the CAPS curriculum) could create inviting and motivating learning environments for learners. This, we claim, holds affordances for promoting SDL in our schools and to better prepare learners for a complex 21st century.

■ Summary

This chapter focuses on the holders of IK as self-directed learners and lessons that can be derived for science education in South Africa. Two cases are presented on how the holders of IK are self-directed learners. The first case deals with learning about edible and medicinal plants, which is need-driven, and how it meets the criteria for SDL. The authors reflect on examples of South African cultural groups' knowledge of useful plants, as encapsulated in the EKI. The second case explores SDL in an ethno-veterinary context, focussing on SDL to effectively combat ticks in cattle – an important aspect in the lives of subsistence farmers in South Africa. The latter part of the chapter focuses on how these insights could be implemented in the STEM school curriculum, in order to promote SDL for a complex 21st century.

Chapter 5

Arguing for the inclusion of indigenous knowledge in the STEM curriculum: Possibilities and challenges

Josef de Beer
Research Unit Self-Directed Learning, Faculty of Education, North-West University, Potchefstroom, South Africa

Ben-Erik van Wyk
DST-NRF South African Research Chair of Indigenous Plant Use, Department of Botany and Plant Biotechnology, Faculty of Natural Sciences, University of Johannesburg, Johannesburg, South Africa

Introduction

It is common knowledge that the quality of Science and Mathematics teaching in South Africa needs to be improved (this has been discussed by Mentz and De Beer in Ch. 2). Literature

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has provided reasons, such as underqualified teachers and under-resourced classrooms, among others, for the dismal performance of South African school learners in international benchmark tests such as Trends in International Mathematics and Science Study. However, a reason for the poor performance that is not always considered is the marginalisation of the affective domain of human functioning (e.g. the role of student interest and motivation in the learning process). Such disregard for affective outcomes often lead to disinterest, and students end up not appreciating the role of science and technology in our everyday lives (Buma 2018; De Beer 2015). Learners do not enter the STEM classroom as tabula rasa, and they almost always have localised IK that could contextualise the often abstract ('Western') curriculum content better. This, we argue, could make science education more relevant and meaningful for learners and cultivate their interest in science. Gibbons' (2000) notion of 'Mode 2 knowledge production' (Gibbons 2000:159, 161) could be realised by following more Afro-centric approaches that are more sensitive towards cultural contexts in the Natural Sciences classroom. With this, we do not argue that the knowledge constructs (principles and laws) that characterise global Science and Mathematics curricula should be overlooked. These principles and laws will always be the backbone of the substantive nature of the Natural Sciences. Instead, we advocate for 'glocalisation' (Patel & Lynch 2013) – globally competitive curricula, with local relevance.

De Beer (2015) refers to Zaruwa and Kwahe (2014), for example, who show how an abstract concept, such as endothermic reactions in a chemistry lesson, could be contextualised by introducing traditional leather tanning, in certain contexts. In some cultures, cattle bones were crushed to produce calcium powder, to which potash was added. Subsequently, bird dung was added to the calcium and potash mixture, and the resultant paste was smeared on the soaked skins. In Figure 5.1, science teachers engage with a holder of IK, who illustrate how skins were traditionally treated. Zaruwa and Kwahe (2014) show that bird droppings are rich in uric acid, which lowers the pH. The

Source: Photograph taken by Josef de Beer, exact date and location unknown, published with permission from Josef de Beer.

FIGURE 5.1: Science teachers learning from the holders of IK about leather tanning, at the Mphebatho Museum, North-West province, as part of a SLP.

lower pH could enhance the denaturation of proteins, and this could act as a catalyst for an endothermic reaction with water molecules. For many rural learners, who might struggle with the abstract concept of endothermic reactions, such contextualisation might provide better access to the learning content.

Another example – infusing IK on medicinal plants into the natural and Life Science curricula – highlights the fact that scholars disagree on how (and if) this border-crossing should be done. Although Western science and IK share a mutual knowledge domain, there are big differences in their epistemologies and methodologies (Onwu & Mosimege 2004). Whereas authors such as De Beer and Whitlock (2009) argue for an inclusion of IK in the science curriculum where the shared tenets of Western science and IK are emphasised (e.g. both Western and indigenous scientists formulate hypotheses, develop experimental designs, make observations and draw conclusions), other authors (e.g. Onwu and Mosimege 2004) oppose this. The latter authors are of the opinion that it would be a mistake to subject IK to the same verification processes as Western science. They hold the outlook that, as these are two different knowledge systems, the verification processes should be different too.

South Africa has both rich biodiversity and cultural diversity. The country has some 30 000 species of flowering plants (Van Wyk & Gericke 2018), and the different cultural groups in the country use these plants for a variety of reasons, for example, as food and drink, as cosmetics, as medicines and health tonics, and for arts and crafts. In the Life Sciences classroom, a teacher can engage learners in simple laboratory protocols, such as the Kirby–Bauer technique, where they can determine the antimicrobial qualities of medicinal plants. A simple way of determining the sensitivity of a microorganism to an antimicrobial substance (e.g. an active ingredient in a medicinal plant) is to use agar plates that are inoculated with microorganisms and to let the active substances in the plant material diffuse into the agar medium (De Beer & Whitlock 2009; Mitchell & Cater 2000). Growth-inhibition zones will be seen if the chemical substances are effective as antimicrobial agents. De Beer and Whitlock (2009) describe a simple technique suitable for the classroom, where learners have to draw upon the syntactical NOS in performing the activity. In a similar vein, De Beer and Van Wyk (2011b) describe a simplified rapid appraisal methodology, using the Matrix Method, for doing ethnobotanical surveys in the Life Sciences classroom. The advantage of such border-crossing is that the learners come to a better understanding of the similar nature of Western and indigenous science.

In both pre- and in-service teacher education, teachers should be trained to effectively infuse IK into the classroom – a focus pertinent in Chapter 2 and Chapter 5 to Chapter 8 of this book. However, according to Onwu and Mosimege (2004), teachers should also be made aware of the unique characteristics that distinguish IK from Western science.

Source: (a, b & c) Photographs taken by Josef de Beer, exact date and location unknown, published with permission from Josef de Beer.

FIGURE 5.2: (a, b & c) Teachers engaging in an adapted Kirby–Bauer technique in the laboratory, during a SLPs.

Next, we will explore the affordances of such inclusion of IK in the formal curriculum from an Embodied, Situated and Distributed Cognition (ESDC).

The affordances of indigenous knowledge in the science classroom: Justification from an embodied, situated and distributed cognition perspective

Research in cognition and neuroscience has resulted in ESDC becoming popular as a framework (Hardy-Vallée & Payette 2008) to study and to understand cognition. It postulates that cognitive processes are not limited to symbolic processing in the brain and that cognition and learning entail more than simply chemical synaptic transmission and communication between neurons in the brain. A person's regular, normal activities, such as exercise, stress and social interaction, all affect synaptic strength (Dubinsky, Roehrig & Varma 2013). Embodied, situated and distributed cognition claims that 'cognition is physiologically embodied, socioculturally situated, and ostensibly distributed among individuals' (Chahine 2013:434). Chahine makes a strong case that cognitive processes involved in learning are inherently multimodal and that 'bodily movement, use of manipulatives, acts of drawing pictorial displays, verbal language, use of written symbols play a role in understanding concepts' (Chahine 2013:435). Chahine (2013:435) states that 'high-level cognitive processes are fundamentally galvanised by multimodal sensorimotor actions that operate above and beyond the neuronal networks in the brain'. The ESDC framework is underpinned by the notion that cognitive processes are embedded physiologically in action, situated in the sociocultural world and distributed among agents, artefacts and external structures (Chahine 2013:434; Hardy-Vallée & Payette 2008). It is important to recognise the social context of learning, as well as the sociocultural background of learners. Jegede and Aikenhead (1999) are of the opinion that, when teaching and learning are informed by the learner's worldview and cultural background, smooth border-crossings can be obtained.

Various chapters in this book focus on the learning of IK, as facilitated by a project funded by the NRF and the Fuchs Foundation. This project was built on the understanding that learners' 'cognition is motivated and embodied by their ability to use multiple modalities and translations within and between such modalities' (Chahine 2013:435). Hill (2000:80) states that ESDC advocates for a different perspective of 'the search for cognition from inside of the skull to an exploration of the relations that hold between animals (made up of bodies and brains) and their surroundings'. In the project (refer to Ch. 5 and Ch. 6 in particular), teachers engaged with holders of IK at museums, and we argue that their physical (bodily) involvement in activities such as beer-brewing, leather tanning or making music (and learning about fractions) using boomwhackers (see Ch. 6), in a sociocultural space (where they collectively construct knowledge), support learning and cognition. In Vygotskyan (1978) terms, the teachers' learning is scaffolded across the ZPD, and learning first takes place on the social plane (collectively engaging in activities at the Museum with colleagues, facilitators and holders of IK, as can be seen in Figure 5.3), and it is then (2nd plane) internalised, where teachers reflect on their learning. Ideally, this knowledge and skills would be transferred to the teachers' classrooms.

Source: (a & b) Photograph taken by Josef de Beer, at the Bakone Malapa Museum, date unknown, published with permission from Josef de Beer.

FIGURE 5.3: (a & b) Embodied cognition at the Bakone Malapa Museum in Polokwane.

In Figure 5.3, teachers, with the assistance of the holders of IK, engage in learning activities such as brewing (left) and the mechanics behind the bow and arrow. This, we argue from an ESDC perspective, enhances cognition.

Addressing the 'missing link' in STEM education: The affective domain

We feel, therefore we learn

(Immordino-Yang & Damasio 2007:3)

Research in neuroscience highlights the role of the affective domain in learning. Immordino-Yang and Damasio (2007) warn that:

> [/]n teaching students to minimize the emotional aspects of their academic curriculum and function as much as possible in the rational domain, educators may be encouraging students to develop the sorts of knowledge that inherently do not transfer well to real-world situations. As prefrontal damage patients show, knowledge and reasoning divorced from emotional implications and learning lack meaning and motivation and are of little use in the real world. (p. 9)

Dubinsky et al. (2013) explain this in terms of synapses that become stronger when activated simultaneously by multiple inputs. Thus, a combination of sensory perception, motor tasks and emotional involvement will strengthen learning and ensure its retention. A classic example to illustrate this point is the events of 9/11, when the Twin Towers of the World Trade Centre in New York were destroyed in terrorist attacks. Older readers will probably be able to exactly tell what they were doing on this particular day when the news broke. This is because the emotional experience ensured that this event is stored in the long-term memory of a person.

Despite the fact that research highlights the role of the affective domain in learning, the South African schooling system generally neglects affective outcomes and emphasises cognitive learning outcomes (Buma 2018). One of the reasons for this is the 'mania for assessment' (Mbembe 2016) that results in pedagogies that favour transmission-mode, teacher-centred approaches (such as 'chalk-and-talk') at the expense of more inquiry-learning approaches (Ramnarain & Schuster 2014). The latter, we argue, better addresses affective outcomes.

Teachers should specifically plan affective outcomes. Rotherham and Willingham (2010:17) said about the achievement of 21st-century skills that it is often 'a matter of chance rather than the deliberate design of our school system [...] we cannot afford a system in which receiving a high-quality education is akin to a game of bingo'. We would like to make the same claim regarding the affective domain. Developing students' interest in the science curriculum should be intentionally planned for. And, we claim, IK holds affordances in putting the affective domain centre stage.

In Chapter 3, De Beer and Mentz argue that the holders of IK were, and still are, self-directed learners in many cases. These authors claim that formal science education can learn a great deal from these IK holders. One of the characteristics of learning in such informal environments is that the affective domain is central. Learning is based on real, authentic problems, which ensure learner interest and motivation. The SLPs that are discussed in this chapter, as well as in Chapter 6 and Chapter 9, were therefore designed to promote the affective domain, among others, by contextualising IK in terms of real-life and authentic problems to be solved.

Krathwohl, Bloom and Masia (1964:35) developed a five-level hierarchy for the affective domain. In ascending order, the hierarchy includes the following:

- Receiving – developing an awareness of a phenomenon and a willingness to respond.
- Responding – active participation with the phenomenon.
- Valuing – showing an appreciation of the phenomenon.
- Organisation – incorporating the new knowledge (phenomenon) within a cognitive structure or worldview.
- Characterisation – the new phenomenon becomes part of a person's value system.

During the SLP, teachers' learning was scaffolded, keeping this hierarchy of the affective domain in mind. An awareness of IK was firstly created, and teachers – through various learning activities – actively engaged with IK. Through multimodal engagement in the learning process, the data obtained showed that teachers started to value IK and such border-crossing in the classroom (refer to Ch. 2, Ch. 5 and Ch. 6). However, sometimes, radical conceptual change is needed, where teachers hold worldviews that cannot be reconciled with the tenets of IK.

It is hoped that the SLPs assist teachers in developing an appreciation for IK and a keen interest and motivation to address it in their classrooms. This might spark enthusiasm in the learners and, in turn, provide a new generation of scientists to take South Africa forward. Thabo Mbeki (1998) expressed the following viewpoint in his African renaissance speech of 1998:

> Africa's renewal demands that her intelligentsia must immerse itself in the titanic and all-round struggle to end poverty, ignorance, disease and backwardness, inspired by the fact that the Africans of Egypt were, in some instances, two thousand years ahead of the Europeans of Greece in the mastery of such subjects as geometry, trigonometry, algebra and chemistry. (n.p.)

Perhaps, the new generation of scientists will find inspiration in the country's rich IK, to solve problems like the HIV and AIDS pandemic and the high unemployment, to mention but two problems that the country grapples with.

Objections to teaching indigenous knowledge and controversial conceptual change

Mothwa (2011) and De Beer and Mothwa (2014) have shown that there are many teachers who have objections to teaching IK. One reason for this opposition is teachers' negative perceptions of IK, which are often fuelled by naïve understandings of the tenets of both IK and science. De Beer and Mothwa (2014:461–462) have captured teacher responses on IK such as '[e]ish [...] some of the (IK) things cannot be scientifically proven'; '[m]any of the learners have negative attitudes towards IK because it is against their religious beliefs'. Cronje (2015:211) captured similar responses from some teachers who said 'it is an ethical problem, as you can be accused of teaching pseudoscience' and 'families sometimes think it is witchcraft'.

The above authors have shown that Christian teachers often reject IK owing to its holistic (including metaphysical) nature. These teachers would refer to 'sangomas' or 'diviners' who make contact with the ancestors. Mokgobi (2014:2–3) describes the ancestors as the 'living-dead', compassionate spirits, who act (according to the beliefs of certain cultural groups) as mediators between people and God. An objection from a Christian perspective would be that Christians communicate directly with God, through Jesus Christ, while some traditional African believers communicate with God through the medium of deceased relatives (Mokgobi 2014:26).

In the above-mentioned case, some teachers might experience conflict between a phenomenon (e.g. IK) and their own worldviews (e.g. Christian values). Where IK is in conflict with the religious beliefs that a person holds, conceptual change might be needed. The underpinning theory of conceptual change is Piaget's (1970) cognitive model and schema theory. Piaget (1970:706) would argue for either the 'assimilation of external elements into evolving or completed structures' if the differences are negligible, or for 'accommodation (that) is necessary to permit structural change, the transformation of structures as a function of the new elements encountered' (Piaget 1970:708), where the differences are major.

Carey (1991) is of the opinion that conceptual change requires either the re-assignment of a concept to a different ontological category or the creation of new ontological categories (Vosniadou, Vamvakoussi & Skopeliti 2008). In order for a learner's knowledge and understanding to move from his or her 'common sense' conceptions or naïve understandings to more nuanced scientific conceptions, the learner must reorganise or replace the incomplete knowledge structure (Qian & Alvermann 2000). For a person to change well-established concepts is not easy, especially if religion is involved (De Beer & Henning 2013). Pintrich, Marx and Boyle (1993) show that research on conceptual change is often too rational or 'cold', not considering affective factors. De Beer and Henning (2013:3) are of the opinion that, where there is a need for *radical conceptual change*, the transformation would include 'warm' cognition. These authors show that there are many social and historical factors that could either enhance or restrict conceptual change. Considering these social and affective factors would constitute 'warm cognition'. Researchers working in the field of conceptual change generally 'acknowledge the important role played by students' motivational goals, their epistemological beliefs, and various social factors in conceptual change learning' (Qian & Alvermann 2000:60). In this regard, one should recognise the unfortunate history of South Africa. Apartheid South Africa had the notorious *Witchcraft Suppression of Act* of 1957 (Department of Justice 1957). Introduced in 1895, it outlawed all forms of divination. Divination, however, is at the heart of healing in Africa (Ashforth 2005; De Beer & Whitlock 2009:210). Because of such legislation, many people, without first studying African healing practices, are prompted to label it as 'witchcraft'. In the section entitle 'Should the metaphysical component of indigenous knowledge necessarily be seen as "pseudoscience"?', we critically look at some traditional healing practices that might be seen as 'witchcraft', and we show that there are often very plausible explanations for these practices.

Hynd (2003) suggests that *belief change* should also be considered when studying conceptual change. According to Hynd, true conceptual change does not only refer to developing a better understanding of a phenomenon but also requires *acceptance* of the phenomenon.

This places a big responsibility on science teachers. Research shows that (internationally) students have naïve understandings of the purpose, nature and tenets of science (Qian & Alvermann 2000). These authors (Qian & Alvermann 2000) state:

> [*T*]hat students who hold immature beliefs are less likely to acquire an integrated understanding of particular science concepts, and they are also less likely to change their conceptions once they are formed. (p. 59)

The epistemological border-crossing between IK and Western science, advocated in this book, asks of the teacher to have the necessary knowledge and skills to scaffold the learners' conceptual development, in order to have nuanced understandings of the tenets of Western science and indigenous science. This, however, places pressure on teacher educators to ensure that the NOS and IK is adequately addressed in pre- and in-service teacher education.

■ Should the metaphysical component of indigenous knowledge necessarily be seen as 'pseudoscience'?

Cronje, De Beer and Ankiewicz (2015) analysed the tenets of science (as identified by Abd-El-Khalick, Bell and Lederman 1998) and IK (as identified by Cronje 2015). These authors show that Western science and IK share several tenets – both have an empirical nature, are characterised by their tentative nature (theories are subjected to change, based on new knowledge and insights) and are inferential. However, there are also notable differences. Whereas IK is holistic in nature, science is often reductionistic (Cronje et al. 2015). Ongunniyi (2007:965) describes 'indigenous knowledge as a conglomeration of knowledge systems' that include science, religion, psychology and other fields. For this reason, IK also has a metaphysical nature.

Gorelick (2014:43) states that 'often indigenous sciences are construed as pseudoscience, despite being as sophisticated and nuanced as Western sciences'. This author then shows – as do Cronje et al. (2015) – that Western and indigenous sciences have common procedures; both 'start with prior probabilities (hypotheses); those priors are updated with new data (observations), to form posterior probabilities, or auxiliary hypotheses' (Gorelick 2014:44). The author views science as anything that is Bayesian, *sensu lato*, and thus uses terminology common in falsificationism.

Gorelick (2014) expresses the following warning:

> We need to distinguish sense from nonsense, and distinguish science from pseudoscience. But we must also realize that westerners do not hold a monopoly on sense and sensible ideas. Judging from the environmental damage wrought by Western societies, it seems that indigenous perspectives might be more sensible than Western ones. (p. 51)

Gorelick refers to two differences that might fuel the chasm between Western science and indigenous science. Very often Western science is saturated with 'jargon' (Gorelick 2014:51), whereas indigenous sciences is not characterised by such complex terminology. Furthermore, indigenous science is often characterised by the embracement of metaphors, whereas Western science has shunned the role of metaphors.

In this regard, we would like to use a few examples from the field of ethnobotany to show that there are often plausible explanations for what, at first sight, might appear to be 'pseudoscience'. In the examples that follow, we show that:

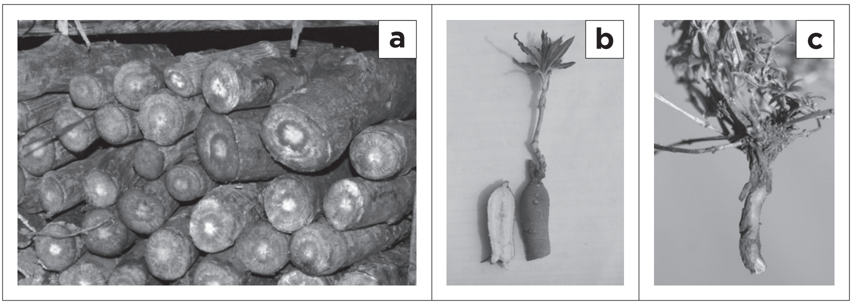
1. effective plant use is sometimes misunderstood owing to the terminology used (e.g. plants used to keep 'evil spirits' away, while the plants are effective antiseptics, and culturally people might have assigned the cause of disease to 'evil spirits')
2. some treatments should be viewed as psychological, rather than medical
3. in IKS as oral traditions, metaphors are often used, owing to their mnemonic value, to ensure that people benefit from cultural knowledge.

Impinda (*Adenia gummifera*) and magic

The very poisonous creeper '*impinda*' (*Adenia gummifera*) is a common plant sold at traditional markets. A decoction of the bright-green stems is traditionally sprinkled around the house to inhibit 'evil spirits' (Van Wyk 2015). In Western households, bleaches and antiseptic products are used for the same purpose, namely, to inhibit microorganisms. For people with IK, who are often illiterate and who do not have microscopes to see microorganisms, 'evil spirits' is the terminology used to describe the germs that cause diseases, and they have realised that '*impinda*' is an effective antiseptic (De Beer & Van Wyk 2016). This serves as an illustration of Gorelick's (2014:51) argument that jargon does not necessarily constitute good science and that 'the best Western science lacks jargon'. Through careful observation, IK holders have realised that *impinda* is a plant with strong antimicrobial properties, which could be used in household hygiene.

Witvergeet (*Asclepias crispa*) and *rooivergeet* (*Galium tomentosum*)

Witvergeet (*Asclepias crispa*) and *rooivergeet* (*Galium tomentosum*) are powerful medicines in the Khoi-san tradition. The concept of a plant causing forgetfulness in a person is found



Source: (a, b & c) Photographs taken by Ben-Erik van Wyk, exact date and location unknown, published with permission from Ben-Erik van Wyk.

FIGURE 5.4: (a) Stems of *Adenia gummifera* as they are sold on *muthi* markets; (b) *Witvergeet*, *Asclepias crispa*; and (c) *Rooivergeet*, *Galium tomentosum.*

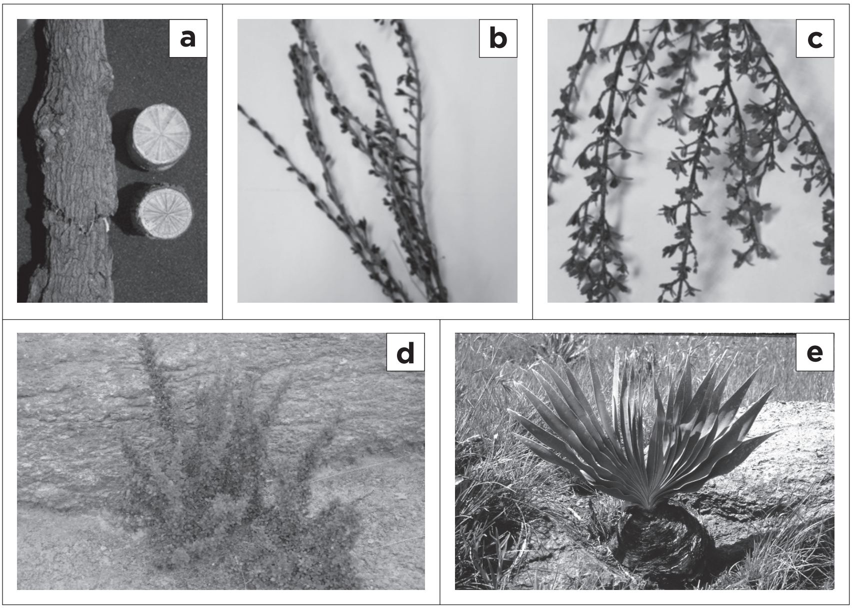
in many cultures and is perhaps a psychological treatment to overcome bereavement and the hardships of the hunter–gatherer lifestyle (De Beer & Van Wyk 2016). However, one might also pose the hypothesis that these plants contain chemical substances that, for example, influence neurotransmitters in the brain. Wink and Van Wyk (2008) show that plants contain many secondary metabolites such as alkaloids, cyanogenic glucosides and polypeptides that are psychoactive. Research on these plants may, in the future, provide plausible explanations of how these plants help people 'to forget'. Van Wyk and Wink (2004) use an interesting example to illustrate that Western science often – hundreds of years later – provides explanations for indigenous practices. These authors point to the use of lime fruit (*Citrus limon*) by the British sailors of yore to overcome scurvy. In the olden days, the use of lime to prevent scurvy was probably seen as metaphysical or 'magic'. It took 200 years for modern science to provide a rationale for this practice, with the discovery of Vitamin C.

Dawidjiewortel (*Cissampelos capensis*)

The *Dawidjiewortel*, *Cissampelos capensis*, has medicinal uses such as to treat pain, diarrhoea, colic, diabetes, tuberculosis, and stomach and skin cancers (Van Wyk & Gericke 2018; Van Wyk, Van Oudtshoorn & Gericke 2000). However, there are also other uses, such as carrying the underground stem as a good luck charm or chewing it to clear the mind and improve mental alertness. The rhizomes may also be burnt in a house to protect it from unwanted influences. The feelings of safety and wellness associated with the latter uses may be linked to the high levels of bisbenzyltetrahydroisoquinoline alkaloids, which have a sedative effect (De Beer & Van Wyk 2016; Van Wyk et al. 2000). Wąsik and Antkiewicz-Michaluk (2012) indicate that the alkaloids have an influence on dopaminergic neurons. Wink and Van Wyk (2008) also show that it is a muscle relaxant. The biochemical and pharmacological research provides some evidence that there are plausible reasons for the plant's use.

The resurrection bush, *Myrothamnus flabellifolius*

An interesting example of African psychology can be found in the use of *Myrothamnus flabellifolius* ('uvukwabafile' or 'opstandingsplant') – see Figure 5.5. Van Wyk (2015) flags an interesting characteristic of this plant, namely, that its leaves become brown and curl up in the dry winter months, giving it an almost dead appearance. If placed in water, it miraculously turns green within a few hours. This plant is used to treat people suffering from the trauma of the death of a beloved or depression (C. Mutwa, pers. comm., n.d.). The patient would be instructed by the traditional healer or African psychologist to put the seemingly dead plant in a glass filled with water and place it on a window sill.



Source: (a, b, c, d & e) Photographs taken by Ben-Erik van Wyk, exact date and location unknown, published with permission from Ben-Erik van Wyk.

FIGURE 5.5: (a) *Dawidjiewortel* (*Cissampelos capensis*), (b) *Myrothamnus flabellifolius* twig at 0 h, (c) *Myrothamnus flabellifolius* at 24 h, (d) the resurrection bush (*Myrothamnus flabellifolius*) and (e) the Bushman poison bulb, *Boophone disticha*.

Within a few hours, the patient experiences the 'miracle' of the plant 'becoming alive'. This serves to show the patient that there is always hope and that there is life after death (Van Wyk & Gericke 2018:126). This serves to illustrate the holistic nature of African medicine, as a form of IKS.

The poison bulb, *Boophone disticha*

The Khoi-san people believed that the bulb of *Boophone disticha* (*gifbol*; *incwadi*; *leshoma*) has the power to transport the dead through the doorway of the spirit to the life hereafter. It has traditionally been used for mummification (Van Wyk & Gericke 2018). An interesting discovery was that of the 2000-year-old Khoi-san mummy in a cave in the Baviaanskloof mountains in South Africa. The mummy was covered in a thick layer of *Boophone* bulb scales. The alkaloids are known for their narcotic activity. This powerful hallucinogen is sometimes still used in male adolescent initiation rites and the initiation of diviners (Van Wyk & Gericke 2018). In the Kalahari region of southern Africa, it plays an important role in the traditional San trance dance, facilitating the passage to the 'other world' and typically with a young apprentice appointed for the purpose of ensuring that the healer makes a safe return.

The use of *Aristaloe aristata* to protect against lightning

From the examples of evil spirits (*Adenia*) and journeys to other worlds (*Boophone*), it is clear that seemingly inexplicable and life-threatening, traumatic phenomena have led to innovative attempts at neutralising them. There are several examples of plants that are used in the lightning-prone Drakensberg region (Lesotho and the eastern Orange Free State) to ward off lightning or to protect people against lightning (Moffett 2010). In the Eastern Cape province, *Aristaloe aristata* (previously *Aloe aristata*), known as *mthithibala* in isiXhosa and *umathithibala* in isiZulu, is well-known for its use as a protection against lightning, for which it is grown in a container on rooftops of huts. The related *Gasteria croucheri*, *Haworthia fasciata* and *H. limifolia* have the same vernacular names and are also used for protection against lightning (Hutchings 1996). It is tempting to speculate that these small succulents with their erect and sharp-tipped leaves could conceivably act as protective devices from a lightning strike, with the metal tin in which they are typically grown serving the purpose of a conductor. Although sharp-tipped devices are no longer considered better that blunt-tipped ones, it is noteworthy that the principle of electrical discharge from a capacitor was originally demonstrated (by Benjamin Franklin) using a sharp-tipped needle (Krider 2006).

The use of plants for protection is perhaps most logically explained by the psychological effects that they have on scared and anxious people. The act of at least trying to do something (rather than being a passive and a helpless victim) probably has a powerful psychological effect. The practice among Afrikaner people to cover mirrors during lightning storms may have the same psychological basis and physiological effect, namely, to relax and reassure.

The power of metaphor: *Dicoma schinzii*, the *Kalahari koorsbossie*

Indigenous knowledge is often captured in metaphor. St. Clair (2000:86) notes that, in cultural knowledge, 'metaphors provide a perspective on knowledge just as scientific paradigms provide a perspective on theoretical knowledge'. One very gripping anecdote is that by Van Wyk and Gericke (2000), also described in Dugmore and Van Wyk (2008), on the 'story of the shadow of the black-shouldered kite'. Birds are often metaphors in African IK and often of fever. The story states that the shadow of the black-shouldered kite, when it falls on a baby, could result in illness (febrile convulsions). These convulsions are easily recognised through the spastic movements of the baby's arms (similar to the movements of the wings of the black-shouldered kite), as it hovers over its prey. People believe that, if the condition goes untreated, the baby could develop feathers on his or her arms. Upon closer inspection, the mnemonic value of the story becomes clear. As mentioned, in African mythology, birds are often used to describe fever. It is interesting to note that birds have a body temperature of about 40°C, as compared to the human temperature of 37°C. The symptoms can be easily remembered through the story of the black-shouldered kite, which people often see around them, regularly reminding them of the 'threat that the bird poses to babies'. The feathers on the arms is a description of the 'gooseflesh of fever'. The treatment is to (internally and externally) use *Dicoma schinzii* (*Kalahari koorsbossie*).

St. Clair (2000:97) shows that visual metaphors provide a dominant mode of information processing.

Source: Photograph taken by Ben-Erik van Wyk, exact date and location unknown, published with permission from Ben-Erik van Wyk.

FIGURE 5.6: A San woman with *Dicoma schinzii.*

A rationality index for 'magic' plants?

Our hypothesis is that there are often very good explanations for what seems to be 'magic' in IKS. Where plants are used to expel 'evil spirits', as in the case of *Adenia gummifera*, these plants often have antimicrobial qualities that could inhibit the growth of pathogenic bacteria or fungi. Other plants have powerful symbolic uses when employed in psychological treatments that constitute a holistic approach, which is typical of African traditional medicine. One such example is the use of *Myrothamnus flabellifolius* to treat depression. Metaphors are described by St. Clair (2000:85) as follows: 'Visual metaphor is a term that designates how visual space is organised as a means of sharing cultural and social knowledge'. Metaphors are therefore often used to ensure that this oral IK is passed on to future generations (as it is often not recorded in book form). Mythology is often rich in metaphors, and the story ensures that the message lives on in people's memories, because the various critical elements and facts are connected and woven into a 'mnemonic network'. Coman et al. (2016) state that the development of shared memories in communities occurs in dynamic mnemonic networks. An example here is the metaphor of the black-shouldered kite.

De Beer and Van Wyk (2011a) developed two indices for ethnobotanical studies, namely, the EKI and the species popularity index. The examples provided here suggest the need for another index, namely, the *Rationality Index for Magic Plants* (RIMP) (De Beer & Van Wyk 2016). Clearly, there is a very rational and scientifically plausible explanation for the use of a plant such as *Adenia gummifera* as an antiseptic, which sheds light on the 'magical' use to 'suppress evil spirits'. This would result in a relatively high RIMP. In the case of the use of a magic plant like *Galium tomentosum* to break witchcraft spells, one senses an irrational and highly implausible use of the plant. In such a case, the RIMP would be low. However, allowance should be made for psychological and intangible mind-altering effects that may be as real to the sufferer of anxiety or trauma than the physical or biochemical interventions that can be more readily explained.

The formula for calculating RIMP therefore needs to make provision for both the physical and the intangible components of 'magic'.

To conclude, one needs to realise that IKS are holistic, lacking in jargon (like the best Western science, according to Gorelick), and are often captured in metaphor. Gorelick (2014) states that acknowledgement is needed:

> [*T*]hat there are two systems of knowledge both of which are empirically testable and both of which are concerned with understanding and guiding practical activity within the same domain of phenomena. (p. 51)

Implications for pre- and in-service teacher education

As mentioned earlier in the chapter, STEM teachers have to support students' learning and create learning opportunities that will facilitate the development of nuanced understandings of the nature of Western and indigenous science. Unfortunately, many teachers themselves do not have a good understanding of the tenets of science and IK, as can be seen in Table 5.1.

The above pre- and post-intervention data, obtained at the start of a SLP for teachers and at the end of the SLP, flag a perturbing trend. Of the participating teachers, only 7.6% had informed views on the tenets of science and 15.4% on the tenets of IK, at the commencement of the programme. Abd-El-Khalick et al. (1998) show that a relationship exists between teachers'

TABLE 5.1: Teachers' views on the NOS and views on the nature of IK.

View Type	VNOS (pre) (%)	VNOS (post) (%)	% change	VNOIK (pre) (%)	VNOIK (post) (%)	% change
UI	15.4	7.7	<7.7	3.8	0	<3.8<
PI	77	69.2	<7.8	80.8	53.8	<27
I	7.6	23.1	>15.5	15.4	46.2	>30.8

Source: Cronje (2015:198).
UI = uninformed view; PI = partially informed view; I = informed view; VNOS, views on the nature of science; VNOIK, views on the nature of indigenous knowledge.
Note: These data refer to an intervention which was presented to science teachers in Johannesburg from 01–03 July 2013, facilitated by Cronje and De Beer.

views on science and how they teach. If teachers do not have a good understanding of the tenets of science, they might favour transmission-mode, 'teaching-to-the-test' approaches, at the expense of inquiry approaches that better capture the tenets of science (Ramnarain & Schuster 2014). Table 5.1 shows that SLPs can be effective in providing teachers with more nuanced understandings of the NOS and IK. There was an increase of 15.5% in the post-test in teachers (23.1%) having informed views of the NOS. In the post-test, 46.2% of teachers had informed views of the nature of IK, an increase of 30.8%.

During such interventions, teachers should be sensitised towards effective pedagogies to teach IK in the STEM classroom. Qian and Alvermann (2000:68) suggest that an effective approach to foster 'students' mature beliefs is to provide students with opportunities to criss-cross the landscape of a complex concept (i.e. to examine the concept from different perspectives)'. In the SLPs reported on by Petersen, Golightly and Dudu in Chapter 5, such complexity was explored in a CL fashion, by making use of De Bono's thinking hats. Teachers engaged in exploring IK from various perspectives.

A problem flagged by Jautse, Thambe and De Beer (2016) is that teacher educators at HEIs often do not have the requisite knowledge and skills to train student teachers in such border-crossing and infusing IK into curriculum themes. These authors suggest partnerships between universities, holders of IK and museums in offering such teacher education. A problem that also inhibits the infusion of IK into the curriculum is the lack of learning resources. Because of generous funding provided by the Fuchs Foundation, the much-acclaimed *People's Plants* (Van Wyk & Gericke 2018) could be reworked and printed as a second edition in 2018. This book is now provided to teachers during interventions.

Another concern expressed in terms of teacher education is to consider the entire spectrum of South African cultural diversity when infusing IK into the classroom. The focus should not only be on African IK but also on IK of marginalised groups such as the

Source: (a) Ben-Erik van Wyk and Nigel Gericke. 2018. *People's Plants – A Guide to Useful Plants of southern Africa*. Pretoria: Briza Publications, 416 pages. ISBN 978-1-920217-71-6 (hardcover).
(b) Photograph taken by Josef de Beer, exact date and location unknown, published with permission from Josef de Beer.

FIGURE 5.7: (a) Cover image of *People's Plants* and (b) making teaching and learning resources on IK available to teachers.

Khoi-san (Speight Vaughn & De Beer 2018) and Indians (Reddy, De Beer & Petersen 2017). Such a diverse focus in the classroom could assist learners in developing higher-order thinking skills, such as identifying common doctrines of different IKS. Reddy et al. (2017) studied Ayurveda, an ancient IK system that originated in India 5000 years ago, to see how, for the sake of the many Indian learners in South African schools, Life Sciences could be made more accessible and relevant for such students. These authors highlight that there are several characteristics that are common to both African and Indian IKS. In both categories, IK is holistic and often embedded in the spiritual. Ayurveda and African IKS also share the Theory of Signature, which is a primordial concept that one could learn about the useful properties of plants through careful observation (Reddy et al. 2017; Reddy 2019).

The above also poses a problem for teachers. In a culturally diverse classroom, *whose* IK should be taught (De Beer & Mothwa 2014)? Also, teachers do not have sufficient knowledge of all these different IKS. This emphasises the need for promoting SDL among both teachers and school learners. As Knowles (1975) puts it, individuals (should):

> [*T*]ake the initiative, with or without the assistance of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating outcomes. (p. 19)

A teacher and her learners should therefore plan on learning about Xhosa, Zulu, Venda, Afrikaner, Indian and other IK in a SDL fashion, identifying suitable resources (which could include the holders of IK), deciding upon learning strategies (e.g. Reddy et al. [2017] describe how the value of Ayurveda could be explored in the classroom, investigating the antimicrobial activity of important Ayurvedic plants such as garlic and turmeric, using an adapted Kirby–Bauer technique) and evaluating the outcomes (e.g. learners could work on displays at science expos, based on their classroom research).

■ Conclusions and recommendations

From the literature, it seems as if there are two schools of thought regarding the status of IK and the formal science curriculum. Some authors argue that IK differs from Western science in terms of both methodology and epistemology and are therefore not in favour of such border-crossing in the science classroom. In this chapter, we have lent our voices to a school of thought that emphasises the fact that Western and indigenous sciences share many tenets and that such epistemological border-crossing could provide students with more relevant and worthwhile learning experiences. We have based our argument on research in the field of neuroscience and claim that IK provides a vehicle in the STEM classroom to address the affective domain.

We would like to illustrate this with a practical example. While doing our ethnobotanical work in the Hantam area in 2009–2012, we interviewed several people to establish their EKI (De Beer 2012;

De Beer & Van Wyk 2011a; De Beer & Van Wyk 2011b). These participants included Jakob and Martiens Thys. After the study was completed, for the sake of complying with good research ethics, we donated copies of the research to the Calvinia Library. Years later, in 2017, we started with SLPs for teachers in the Namaqua district (refer to Ch. 5). One of the Calvinia teachers engaged her (Grade 10) learners in an ethnobotanical survey of the region. Henrico Thys, a Grade 10 learner, was so inspired by this assignment, that he went to the library to consult books on the ethnobotany of the region. In the dissertation of De Beer (2012), he saw the photographs of his uncles (Jakob and Martiens), and this inspired him tremendously. This 'knowledge in the blood', in a Jansen (2009) parlance, provided the motivation for Henrico to engage in an innovative study, and this young man indicated his interest to pursue tertiary studies in botany. These are the affordances that contextualised teaching and learning holds.

We conclude with a number of recommendations:

- Higher Education Institutions (HEIs) and teacher educators should consider how student teachers, during their pre-service training, could be best equipped to facilitate such border-crossing in the classroom. More emphasis should be placed in programmes on providing student teachers with nuanced understandings of the NOS and IK.
- The Department of Basic Education should provide more guidance to teachers and subject facilitators on how IK should be incorporated in the CAPS themes.
- In the value chain between the university and schools, a 'third partner' is needed, namely, holders of IK and museums. Also, teaching and learning resources should be developed to facilitate such border-crossing in the classroom. Funders (e.g. in the case of this project, the Fuchs Foundation) should also become partners in infusing IK into the STEM curriculum.
- Self-directed learning provides the key to effective border-crossing in the STEM classroom. In both pre- and in-service teacher education, learning opportunities should be provided that will enhance SDL.

Summary

This chapter navigates the chasm between arguments for the inclusion of IK in the STEM classroom and arguments against such border-crossing. We start off by advocating for the inclusion of IK in the Science and Mathematics curricula from a neuroscience perspective, and we use ESDC as the theoretical framework. In this chapter, the affordances of such epistemological border-crossing are interrogated in terms of the affective domain. By contextualising the often abstract 'Western' curriculum in terms of relevant (local) IK, learners will experience the learning content as more relevant and accessible, and this might foster affective qualities that could enhance SDL. Research that was done among South African teachers during the past decade shows that many teachers, however, are opposed to the teaching of IK. Their arguments include that IK often constitutes pseudoscience, while some teachers feel that IK is in conflict with their own religious beliefs. We have discussed these views by referring to the tenets of science and IK and the controversial conceptual change that is needed to reconcile IK (in its holistic nature) with personal world views. Next, we look at some of the metaphysical aspects of IK – often the reason for marginalising it in the formal science curriculum – namely, 'magic' plants, and we argue that one should look at these aspects from a perspective that takes the local context into consideration. Very often there are plausible scientific explanations for what at first sight might appear to be metaphysics or even pseudoscience. We conclude the chapter by focussing on what the implications of such border-crossing between IK and 'Western science' are in terms of pre- and in-service teacher education.

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Chapter 6

Engaging pedagogies to facilitate the border-crossing between the Natural Sciences and indigenous knowledge: Implications for science teacher education

Neal Petersen[a,b]
[a]School of Mathematics, Science and Technology Education, Faculty of Education, North-West University, Potchefstroom, South Africa
[b]Research Unit Self-Directed Learning, Faculty of Education, North-West University, Potchefstroom, South Africa

Aubrey Golightly[a,b]
[a]School of Mathematics, Science and Technology Education, Faculty of Education, North-West University, Potchefstroom, South Africa
[b]Research Unit Self-Directed Learning, Faculty of Education, North-West University, Potchefstroom, South Africa

Washington T. Dudu[a,b]
[a]School of Mathematics, Science and Technology Education, Faculty of Education, North-West University, Potchefstroom, South Africa
[b]Research Unit Self-Directed Learning, Faculty of Education, North-West University, Potchefstroom, South Africa

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Introduction and problem statement

South Africa remains one of the most unequal societies in the world (Republic of South Africa 2011a). The national development plan (NDP), in its Vision for 2030, predicted in 2011 that the country has the capacity to eradicate poverty over the next two decades. As we are now in 2019, there are only 11 years to fulfil this goal in its totality. To reach this objective, the NDP (Republic of South Africa 2011a:1) suggested that, one that moves from 'a passive citizenry receiving services from the state' to one that 'systematically includes the socially and economically excluded', where people are 'active champions of their own development' and where government works to 'develop people's capabilities to lead the lives they desire'. The NDP further indicated that this approach can be successful on the premise that the standards of education are raised. In this regard, the recent World Bank Group Systematic Country Diagnostic (SCD) for South Africa, which explores key development challenges and opportunities for the country, identifies five binding constraints for tackling poverty and inequality. One of these was that many school and university leavers do not possess the appropriate skills needed for the workplace of the 21st century. According to the Applied Educational Systems (n.d.) website, 21st-century skills comprise 12 abilities that today's students need to succeed in their careers, namely, critical thinking, creativity, collaboration, communication, information literacy, media literacy, technology literacy, flexibility, leadership, initiative, productivity and social skills. To address the insufficient 21st-century skills of its citizens, the SCD report recommended that South Africa needs to focus on children and young adults as the most critical groups of interest. Policy choices having the most impact should, therefore, include the training of schoolteachers and providing affordable university access to poor students (World Bank 2018).

Based on the recent unrest and debates about the decolonisation of the curriculum, Disemelo (2015) argues that many students, although they have physical access to universities, feel disenfranchised because they live in utterly dismal conditions during their studies, and many do not even complete their studies. Zyngier (2004:13) in this regard claims that 'for many marginalised students schools are not seen as the sites of engagement, but of disenfranchisement and alienation'. Schoolwork that is incongruent with a student's cultural commitments can 'assault self-esteem' (Newmann 1996:555). Only 60% of black university students pass their first year, and of those only 15% complete their studies (Le Grange 2016). Many reasons can be offered for this state of affairs, but De Beer and Petersen (2016) argue that one reason may be that students do not have epistemological access to the science curriculum content.

In this chapter, we argue that students' epistemological access to science curriculum content can be improved if they have better access to the curriculum content taught at university and at school. Bolkan and Goodboy (2015) argue that if curriculum content were better contextualised in the life world of the students, it would assist them in better understanding and internalising the content. Gibbons (2000) refers to this type of context-sensitive teaching as Mode 2 knowledge production that addresses the affective domain of teaching. According to De Beer and Petersen (2016), the affective domain is often neglected in science education because too much emphasis is placed on the cognitive domain. According to these authors, the reasons for the neglect of the affective domain are that many science teachers follow a predominantly content-driven, teacher-centred approach, and many science teachers do not possess good PCK. Ramnarain and Schuster (2014) (see Ch. 3) have shown that many schools – especially in townships – are characterised by teaching-to-the-test approaches. Engaging pedagogies such as PBL and CL were introduced as teaching–learning strategies where learners (in this context the term 'learners' refers to any person learning something, whether child or adult, school learner or student) are active participants in their own learning processes. For the purposes of this chapter, the authors define engaging pedagogies as any inductive teaching–learning strategy such as PBL, CL or contextualised learning, where the learners or students are actively involved in the learning process while developing 21st-century skills. This concept will be further elaborated on in the conceptual framework of this chapter. In order to better address the affective domain in science education, we proposed, for purposes of the research reported in this chapter, to infuse IK with science content into the teaching of science. It was hoped that this would facilitate a border-crossing between the Nature of Indigenous Knowledge (NOIK) and the NOS and for the participating teachers to develop a nuanced understanding of the tenets of these two concepts.

The research question around which this qualitative study revolved was: How can engaging pedagogies facilitate the epistemological border-crossing between (the tenets of) science and IK? Research such as this, where science teachers' PCK is developed through the infusion of IK into the science content by using engaging pedagogies, contributes to the debate about the decolonisation of the curriculum. We believe that if the teachers participating in the research implement the newly acquired teaching–learning strategies, it may have a positive influence on the academic performance and SDL of school learners. The positive influence on school learners' academic performance implies that they will be better equipped with 21st-century skills in order to enter the workplace after their school career or to enrol for further studies at a tertiary institution. If tertiary students are exposed to Mode 2 knowledge production, it may well put them in a better position to complete their studies with success. When these school leavers and graduates enter the workplace with the necessary 21st-century skills, it may ultimately improve their quality of life. This might have a further domino effect to eradicate poverty towards the goals of the NDP's Vision for 2030.

Next, the conceptual–theoretical framework on which the empirical investigation rested is described. This is followed by an enumeration of the research findings, a discussion of the findings in the light of the theoretical and conceptual framework(s) and some recommendations.

Conceptual–theoretical framework

The following concepts formed the conceptual framework of this research:

- the affective domain
- contextualised teaching and learning
- engaging pedagogies such as PBL and CL
- tenets of the NOS
- tenets of the NOIK
- science teaching.

These concepts will be discussed in the paragraphs that follow.

Contextualised teaching: Teaching for the affective domain

South African classrooms and lecture rooms are predominantly characterised by a teacher-centred approach to teaching–learning (Petersen 2011; Ramnarain & Schuster 2014). In a teacher-centred approach, also called the traditional teaching approach, learners are passive during the learning process, while the teacher makes all the decisions regarding the curriculum, the teaching–learning methods and forms of assessment (Lak, Soleimani & Parvaneh 2017). One can thus argue that the students are passive recipients of teachers' knowledge. Duckworth (2009) states that teacher-centred teaching and learning actually inhibit students' educational growth. In a teacher-centred approach, the focus is largely on the cognitive domain of teaching, while the affective domain is usually neglected during teaching. Gibbons (2000) refers to such an approach as discipline knowledge production or Mode 1 knowledge production. In this knowledge production mode, teaching–learning experiences are usually not linked to the learners' life world, and they experience the content taught as dislocated from their day-to-day life. By contrast, Gibbons refers to Mode 2 knowledge production or context-sensitive knowledge production.

Mode 2 knowledge is produced in a context of application involving a range of perspectives – it is transdisciplinary, is characterised by a heterogeneity of skills, is socially accountable and reflexive, involves a much-expanded system of quality control and speaks to the affective domain (Gibbons 2000). One of the specific outcomes of the science CAPS curriculum involves the affective domain, stating that 'understanding the applications of science in everyday life, as well as understanding the history of scientific discoveries and the relationship between indigenous knowledge and science' (Republic of South Africa 2011b:11). Science teachers are therefore obliged to teach for the affective domain.

During the research intervention reported in this chapter, science teachers were exposed to Mode 2 knowledge production in designing context-sensitive science teaching–learning experiences. IK, providing the contexts, was infused into the science CAPS content, making use of PBL and CL as examples of engaging pedagogies. In the paragraphs that follow, the tenets of the NOS and the tenets of the NOIK are explained, after which PBL and CL will be deliberated upon.

Tenets of the nature of science and indigenous knowledge

One myth of doing Natural Sciences is that practitioners of science, such as lecturers and teachers, believe that a general and universal scientific method exists (McComas 1998). McComas further states that there is no single scientific method that can be applied by all scientists universally. However, Mentz and De Beer (2017) state that science teachers primarily use the scientific method of investigation as the only empirical approach to find answers about the natural phenomena around them. Allain (2013) argues that one of the root causes for the focus of science teachers on the empirical NOS is that the scientific method is used as the 10 Commandments of science in most school and college textbooks, where the focus is on evidence-based and objective tenets of science (Vhurumuku 2010). This may mean that science learners do not understand the true NOS (Cronje 2015).

This practice is based on the premise that the NOS, as a body of knowledge, is based on facts, laws and theories (Vhurumuku 2010). According to Cronje (2015), an empirical and objective approach to science investigations leads to overlooking the tenets of science as subjective, socially constructed and creative. Human creativity and imagination plays a role in doing science (Abd-El-Khalick, Bell & Lederman 1998). In this regard, Clough (2004) claims that if the NOS is accurately and effectively taught, it will help the students to better understand the role of science in social decision-making.

In order for science teachers to make it a reality in classrooms, what Clough (2006) named 'context of everyday science' and 'authentic science', we propose to infuse IK as an authentic context into science curriculum content.

Indigenous knowledge encompasses a wide-ranging number of characteristics, and there is no single definition for this concept (Senanayake 2006). However, in this chapter, we have used Agrawal's (1995:418) definition of IK, stating it as 'IK is the common sense knowledge and ideas of local peoples about everyday realities of living'. Cronje (2015:322) lists a number of tenets of the NOIK, namely, (1) 'empirical and metaphysical in nature; (2) resilient yet tentative; (3) inferential yet intuitive; (4) creative and mythical; (5) subjective; (6) social, collaborative and cultural; (7) wisdom in action; (8) functional application and (9) a holistic approach'. In Table 6.1, Cronje (2015) draws a comparison between the NOIK and the NOS.

In her research, Cronje (2015) indicated that many science teachers do not possess the necessary PCK to actualise the CAPS curriculum with regard to using IK in their lessons. These authors further argued that the reason for this non-compliance is that teachers do not have an understanding of the NOIK. The intervention, a SLP, which is the focus of the research reported in this chapter, therefore aimed to expose and train science teachers about the NOS and the NOIK in order for them to make the border-crossing between IK and 'Western' science.

TABLE 6.1: Nature of indigenous knowledge framework in relation to the NOS framework.

Tenet no	NOIK	Tenet no	NOS
1	*Empirical and metaphysical NOIK* Nature is real, partly or generally tested and observed. Needs-based experimentation. The universe is orderly, metaphysical and partly predictable.	1	*Empirical NOS* Nature is real, observable and testable. The universe is orderly and predictable.
2	*Resilient yet tentative NOIK* Indigenous knowledge has withstood the test of time, but is constantly changing as a tradition; it is fluid and transformative – linked to people's experiences. It must be kept in mind that the elders' repository of ways of knowing is the truth and is not to be challenged.	2	*Tentative NOS* Science is subject to change and not absolute and certain. It is challengeable by all.
3	*Inferential yet intuitive NOIK* Facts are tested and experimental observations made. Events have both natural and unnatural causes; metaphysical dimensions are important.	3	*Inferential NOS* There is a clear distinction between observations made of nature and deductions or conclusions (inferences) made from observations to explain the causes. All events have natural causes.
4	*Creative and mythical NOIK* Observations and experimenting are not the only sources of ways of knowing. Human creativity, imagination and myths also play a role.	4	*Creative NOS* Observations and experiments are not the only sources of scientific knowledge. Human creativity and imagination also play a role.
5	*Subjectivity of NOIK* Indigenous ways of knowing are based on cosmology and are interwoven with culture and the spiritual. The elders can be influenced by prior ways of knowing and beliefs.	5	*Subjectivity (theory-laden) of NOS* Scientists strive to be objective and culture-free, but as human beings they are subjective and influenced by theoretical and disciplinary commitments, prior knowledge and beliefs.
6	*Social, collaborative and cultural NOIK* Indigenous knowledge is situated in cultural tradition and within a certain historical-political context. It is the consequence of activities connected to everyday life in the natural environment of a group of people. It does not focus on the individual, but on the group and sharing. Indigenous knowledge is locally rooted and ecologically based. It is generated at a specific place by people of that place. Generalisations are relative within a certain context and can be shared among communities and beyond.	6	*Social and cultural NOS* Scientists try to be objective, but science is a human endeavour and is therefore affected by a social and cultural milieu. Scientists do sometimes work individually. Science is generated at a specific place and thus local, but generalised, scientific laws and theories have universal applications.

Table 6.1 continues on the next page →

TABLE 6.1 (Continues...): Nature of indigenous knowledge framework in relation to the NOS framework.

Tenet no	NOIK	Tenet no	NOS
7	*Wisdom in action and NOIK* Indigenous knowledge is generated by practical engagement in everyday life through trial and error experiences. Repetition and ceremonies are methods to aid retention and reinforce ideas. New ideas are rigorously tested in the 'laboratory of survival'.	7	*Methods and NOS* Science knowledge is not generated by a single step-by-step universal method. Scientists use a variety of methods to solve problems and test theories. These methods are usually done in laboratories.
8	*Functional application and NOIK* Indigenous knowledge is not only concerned with what and why things happen in nature but also with what ought to happen. Emphasis is on practical or functional application and skills. Indigenous knowledge is concerned with the everyday lives of people rather than facts, theories and laws.	8	*Theories and laws and NOS* Scientists use theories and laws to explain what, why and how things happen in nature. A scientific law describes what happens, while a theory explains why and how things happen. Scientific laws are causal, rational and logic.
9	*Holistic approach of IK* Indigenous knowledge is 'a conglomeration of knowledge systems' including science, religion, psychology and other fields. Problems and issues are solved in a holistic manner addressing all the smaller parts with no boundaries with the metaphysical world.	9	*Reductionist approach of NOS* Complex phenomena can be broken down into small parts and analysed. The part to whole method is used.

Source: Cronje (2015:44–46).
IK, indigenous knowledge; NOS, nature of science; NOIK, nature of indigenous knowledge.

During the intervention, science teachers learnt about the NOS and the NOIK using engaging pedagogies, namely, contextualised learning, PBL and CL. Participating science teachers also got the opportunity to choose topics from the curriculum to design teaching–learning experiences, suitable for a particular engaging pedagogy as mentioned above. In the paragraphs that follow, the concept of engaging pedagogies will be described with appropriate examples.

Engaging pedagogies

Schools need to 're-engage with the disengaged' (Zyngier 2004:3). This author is referring to the disengaged (alienated) as those learners (and students) that are at risk, disadvantaged or from low socio-economic backgrounds. In the South African context, re-engagement is necessary to reach all school learners and students, from all social spheres, in their places of learning in order to give them a better chance of academic success, which will contribute to social cohesion, social justice, prosperity and peace. Higher levels of engagement in schools will encourage lifelong learning and the development of 21st-century skills (Fullarton 2002).

Zyngier (2004) claims that student engagement can be regarded as an important precursor for learning in students' own lives and for their own learning at school. Newmann (1989:34) defines engagement as 'the students' psychological investment in learning, comprehending and mastering of knowledge or skills'. Ryan and Deci (2009, cited in Saeed & Zyngier 2012) argue that student involvement in learning is a means for students achieving sound academic objectives, which may lead to higher academic achievement throughout a student's life (Zyngier 2008). Zyngier (2004:10) further argues that a 'student-centred pedagogy envisages engagement as implicit in active learning where self-motivation, reflective shared goals setting and student choice are located in the lived experiences of the students'. The Centre for Holistic Teaching and Learning equates engaging pedagogy with 'inductive teaching and learning', which, according to Prince and Felder (2006), is a process of learning where the learners discover facts, rules, procedures and guiding principles by observing examples. This definition of inductive learning opposes deductive learning, where learners are given general rules and principles that they then need to apply in new situations. Inductive learning has the following features in common:

- it is learner-centred, constructivist
- promotes active learning and CL
- is also known as discovery learning.

According to Prince and Felder (2006), inductive learning can be regarded as a concept that incorporates a number of teaching and learning strategies, such as PBL, case-based learning, project-based learning and inquiry learning. For the purposes of the study reported in this chapter, engaging pedagogies is defined as any inductive teaching–learning strategy, such as PBL, CL and contextualised learning, where the learners and students are actively involved in the learning process while developing their 21st-century skills. In the paragraphs that follow, PBL and CL, as examples of engaging pedagogies, will be elaborated upon.

Problem-based learning

The integration of IK into the formal science curriculum requires the implementation of innovative teaching and learning strategies.

One teaching and learning strategy that adheres to this is PBL. Problem-based learning was originally implemented in the medical education curricula in Canada's McMaster University Medical School in the late 1960s (Schwartz, Mennin & Webb 2001). Soon afterwards, PBL was also integrated in Engineering and Nurse Education curricula around the world. PBL has only recently come to the fore in teacher education as well as primary and secondary school education (Borhan 2014; De Simone 2014; Golightly & Muniz 2013). Possible reasons for this are that PBL represents a radical shift in educational thinking from a direct instructional approach to an active learning approach. The integration of PBL in a programme or module necessitates changes in curriculum, teaching, learning and assessment strategies that are often unfamiliar to lecturers, teachers, students and learners (Barron et al. 1998). It is no secret that PBL challenges the dominant cultures of university and school teaching and that teachers, acting as facilitators, may face difficulty in facilitating discussions in collaborative learning environments (Ngeow & Kong 2001). Most authors agree that students and educators have a difficult time with the transition from lecture-based teaching to PBL and need a period of induction and orientation to the processes of how to take responsibility for your own learning (Boud & Feletti 1997; Miller 2000).

In a PBL environment, the focus is on students and learners solving real-world problems, rather than being taught by lecturers or teachers (Borhan 2014; De Simone 2014; Golightly & Muniz 2013). In the PBL process, an ill-structured, real-world problem (one to which there are many possible solutions) is presented to the students first. The students and learners may be organised into small PBL tutorial groups where group members collaborate as a team (Dolmans et al. 2001). The students or learners discuss the problem and formulate more specific learning objectives. These learning objectives are then conceptualised into various learning tasks, whereafter group members have to consult various resources, articles, textbooks and field studies. They come back to the next PBL tutorial session with new information to share and work on the problem together (Lam 2009). After the students or learners have discussed and analysed the learning objectives in their tutorial groups, they formulate multiple solutions to the stated problem (Tick 2007). The different groups can also report back to the rest of the groups on the possible solutions they have formulated. During the PBL process, the lecturer or teacher acts as a facilitator or tutor. The facilitator or tutor guides the conversation between group members, provides appropriate scaffolds that give support to students or learners, monitors the progress and assesses each group member's contribution to the group's work (Schmidt et al. 2009).

In PBL, when the group members are formulating solutions to the stated problem, it is necessary, in most cases, to cross academic disciplinary borders. Interestingly, Dahms and Stentoft (2008) noted that the implementation of PBL may assist in the implementation of Africanised (indigenous) knowledge, owing to the focus on identifying and applying local, formal and informal knowledge in solving local real-world problems, situated in a social context rather than in a textbook. With the implementation of PBL in the school curriculum, learners use local IK, to the local context and to the local needs of the community (Dahms & Stentoft 2008).

In this regard, De Villiers, De Beer and Golightly (2018) are of the opinion that in a PBL environment, IK can be infused into teaching and learning activities based on the tenets of the NOS.

With the design, planning and implementation of PBL activities to infuse IK into the formal science curriculum, it is important to train, assist and guide teachers in the process. To illustrate the contextualisation of a real-world PBL activity in science education, the following example adapted from Golightly (2018) can be used:

> As a Life Science learner in a school situated in a squatter settlement on the periphery of a town in South Africa, you become aware that the Life Sciences learners in your school are absent on a regular basis. In discussions with the different role players as well as the clinic sisters at the nearby medical clinic, the poor health conditions in this squatter camp are identified as the main reason. The governing body of the school asked you and your fellow learners to formulate possible solutions to the poor health problems of learners in the area. (p. 438)

In the above-mentioned real-world, ill-structured problem, the learners working on this problem had access to contextualised local knowledge on living conditions in a low-income area around a town in South Africa, while also having access to substantial scientific knowledge on poor health conditions in low-income areas. Combining the two types of knowledge allows the learners to formulate solutions to problems typical of South African towns and cities.

Unfortunately, teachers in a South African context often lack the PCK to infuse IK into the contents of the sciences curriculum. Against this background, 'the affordances of indigenous knowledge for self-directed learning' project was designed and implemented in a three-day SLP. The purpose of the SLP was mainly to develop the PCK of teachers with regard to the implementation of engaging pedagogies and IK education in order to empower them to facilitate SDL processes in their classrooms (De Villiers et al. 2018). An example of a PBL activity in the SDL is that teachers (in small groups) have to plan a learning opportunity where learners have to determine the efficacy of traditionally used medicinal plants by engaging in laboratory protocol typical of microbiology labs.

Cooperative learning

According to Johnson, Johnson and Johnson-Holubec (2008), groups have existed for as long as there have been humans. In a timeline of the development of CL, Johnson et al. stated that learners have benefitted from teaching one another as early as the 1st century. By the turn of the 19th century, Francis Parker was describing instructional methods of how to structure cooperation in classrooms. During the mid-1960s, these authors trained teachers in America on how to implement CL effectively. Based on literature (ResourcEd 2017), when it comes to group work, the terms collaborative learning and CL come to the fore. Some authors use the terms interchangeably and others as two separate concepts. However, there are some differences and similarities. ResourcEd (2017) lists some of the similarities, for example, both rely on active student participation rather than passive, lecture-based teaching; both require learners to complete a task; the teachers act as facilitators to learning; both create shared learning experiences; and both embrace student diversity. Although there are more differences, the most important difference is that with collaborative learning, students make individual progress in tandem with others while CL involves more inherent interdependence, promoting greater accountability (ResourcEd 2017). In this chapter, we use the two terms as separate concepts and prefer to use the term CL.

Cooperative learning can be regarded as a teaching–learning strategy based on constructivist principles. Sandi-Urena, Cooper and Stevens (2012:701) define CL 'as a student-centred, active learning approach that uses structured situations in which fixed small groups interact in a non-competitive manner to accomplish a common goal'. Johnson and Johnson (1994) define CL as group work that occurs when students work cooperatively in small groups to complete common goals. These authors further argue that CL can only be successful if the following basic elements are present in a teaching–learning experience, namely, positive interdependence, individual accountability, promotive face-to-face interaction, interpersonal small-group skills and group processing. To further optimise the effectiveness of the CL experience, these authors advise that there should not be more than four groups (Johnson & Johnson 1994). The research reported in this chapter leans heavily on CL as described by Johnson and Johnson (1994). These five essential elements, according to the descriptions of Johnson and Johnson (1994), are described below:

- Positive interdependence, perhaps the most important element of CL, is described as the heartbeat of CL or the 'sink or swim together' principle. Positive interdependence occurs 'when students perceive that they are linked with group mates in such a way that they cannot succeed unless their group mates do (and vice versa) and/or that they must coordinate their efforts with the efforts of their group mates to complete a task' (Johnson & Johnson 1994:2). During a CL lesson, positive interdependence can be scaffolded in one of the following ways: 'positive goal interdependence; positive reward interdependence; positive resource interdependence; positive role interdependence' (Johnson & Johnson 1994:2). In the SLP, such CL is particularly relevant. Jautse, Thambe and De Beer (2016) showed that traditionally this element of positive interdependence had been part of learning in informal, IK settings.
- Individual accountability entails that each member in the group is held accountable and responsible for his or her segment of the work in order to reach the common goal. It is important to mention that although the group learns together, it is crucial that 'group members should be better prepared to complete similar tasks by themselves' (Johnson & Johnson 1994:4).
- Face-to-face promotive interaction is defined as individual members of the group encouraging and helping each other in their efforts to reach the group's shared goals. Johnson and Johnson (1994:3) state that 'promotive interaction is characterized by individuals providing each other with efficient and effective help and assistance; exchanging needed resources, such as information and materials; and processing information more efficiently and effectively; providing each other with feedback in order to improve their subsequent performance'; etc. The groups can be physically structured so that members can sit knee-to-knee to facilitate interaction.

- Interpersonal and small-group skills (social skills) are cultivated during a CL activity. These skills include, among others, believing in each other, communicating effectively, accepting and supporting each other, and resolving conflict beneficially.
- Group processing refers to the process during a CL activity where the group members need to determine, through self-reflection and group-reflection, if, or how well, they have achieved their mutual goals. Based on their reflection, the group members need to adapt their plans in order to reach the goal in time.

During a CL activity, the teacher acts as a facilitator in terms of planning the learning experience, making sure that all the resources are in place, and using suitable scaffolds while executing the learning experience. Guided by the curriculum content, the teacher can use one of the following CL teaching methods:

- Jigsaw
- GIG ('Group-Individual-Group')
- Note-taking-pairs
- Cooperative graffiti
- De Bono's thinking hats
- Think-pair-share (Lubbe 2015; Petersen & Mentz 2016).

Cultural-Historical Activity Theory will now be described as the research lens of this study.

Cultural-Historical Activity Theory

Teaching is a complex and challenging career and is characterised by constant and continuous curriculum change and therefore teachers' ongoing need for opportunities for their own professional development. In the study reported in this chapter, in-service teachers attended an SLP with the aim of contributing to participating teachers' PD. Third-generation CHAT, as described by Engeström (1987), was used as a research lens to examine the socially constructed actions of the participating science teachers during and after the SLP. The concept, the ZPD, first coined by Vygotsky (1978), implies that learning takes place on two levels. Firstly, on a social plane and, secondly, on a personal plane where the learning is internalised. For effective learning to take place over the ZPD, a learner needs to be provided with suitable scaffolds by a teacher (facilitator) or a more knowledgeable peer to a point where the learner can act independently and internalise the newly learnt content (Mentz & De Beer 2017).

Cultural-Historical Activity Theory can be used in understanding human cognition by exploring the relationships between people, tools and goals, as they are shaped by social structures, culture and history within a community (Engeström 1987). The activity system can be regarded as the primary unit of analysis in CHAT. (Refer to Ch. 2 for a more detailed discussion on CHAT.) The activity system of this study refers to the professional development of science teachers during an SLP in order to improve their PCK with regard to context-sensitive science teaching as the goal. Engeström (1987) describes an activity system having five elements. The object, or objective, is the product of the activity system in order to meet a human need and usually provides an insight into why people perform different actions (Engeström 2000). The object of the activity system of this study is to develop the subject's PCK (and understanding of the NOS and NOIK) with regard to contextualised teaching. The subject refers to the people engaged in the activity system — the science teachers, in the context of this study. In an activity system, the subject's main goal is to reach the outcome, and in the process, their identities and knowledge are shaped and transformed by interacting with the other elements in the activity system (Roth & Lee 2007). Tools are used to mediate every human action and experience and can be internal, external, psychological or material (Vygotsky 1978). The choice of selecting a tool by the subject directs the way the subject acts in order to reach the outcome (Kaptelinin, Kuuti & Bannon 1995). All the individuals or groups sharing the goal of the activity system constitute the community of an activity system. Because all the individuals usually do not possess all the knowledge and skills to fulfil the goal, they enact different roles with each other (Jonassen & Rohrer-Murphy 1999). The community negotiates a set of rules, and/or uses the sociocultural conventions dictated by the culture of the community to guide the activities of the subject (Trust 2017). 'Division of labour' refers to the different roles of the subject, for example, a teacher, in the activity system — as a facilitator of learning, as a self-directed learner or as a reflective practitioner.

According to Mentz and De Beer (2017), CHAT can be used in one of three ways, on a personal plane, an interpersonal plane or an institutional plane (refer to Ch. 2). In this research, CHAT was used on a personal plane, as described by Rogoff (1995), where the subject is the teacher. Two sub-activity systems, firstly, the science teachers during the SLP (intervention) and, secondly, the same science teachers in their implementation in the classroom after the SLP (Figure 6.1) were compared. The complexities of the 'objects' of the two interlinked sub-activity systems will be highlighted in the discussion below and the 'contradiction of control' (McNeil 2013) between the two objects will also be illustrated.

Source: Photograph taken by Josef de Beer, at the Bakone Malapa Museum, exact date unknown, published with permission from Josef de Beer.

FIGURE 6.1: Working with IK holders at the Bakone Malapa Museum in Polokwane.

Empirical investigation: The short learning programme, research methodology and ethics

The research reported on in this chapter was a large-scale qualitative, design-based project within an interpretative paradigm. The study investigated the integration of IK into the science curriculum through the use of different engaging pedagogies. In order to reach this goal, the researchers developed SLPs in Life Sciences, Natural Sciences and Physical Sciences presented in different cycles to the participating science teachers. Table 6.2 represents a summary of these interventions (presentation of SLPs).

Each cycle of the intervention consists of the following phases:

- Phase 1: Planning of the different SLPs and relevant data collection instruments.
- Phase 2: Development of teaching–learning materials.
- Phase 3: Presentation of the SLPs and data collection.
- Phase 4: School visits to observe participating science teachers.
- Phase 5: Using CHAT as a lens to determine tensions and to identify new design principles to improve the SLPs for the next cycle.

TABLE 6.2: Summary of three cycles of SLPs.

Cycles of intervention	Location of SLPs	Subjects in which SLPs were developed	Number of participants
Cycle 1 (2016)	Polokwane (Limpopo province)	Life Sciences Natural Sciences	62 13
	Potchefstroom (North-West province)	Life Sciences Physical Sciences	8 6
	Kimberley (Northern Cape province)	Life Sciences	37
Cycle 2 (2017)	Calvinia (Western Cape province)	Life Sciences Physical Sciences	37 7
	Lenasia (Gauteng province)	Life Sciences (Focus on Indian IK, Ayurveda)	15
Cycle 3 (2018)	Potchefstroom (North-West province)	Physical Sciences	10
	Calvinia (Western Cape province)	Natural Sciences	16

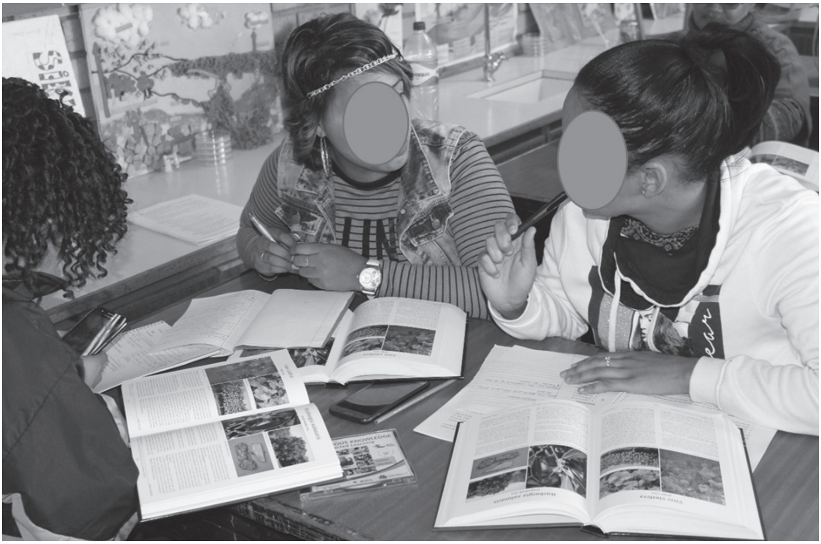
SLP, short learning programme.

Most of the SLPs (see Table 6.2) were presented over a period of 3 days and all the other SLPs over a period of 2 days in the different places as outlined in Table 6.2. (In the case of 2-day-long SLPs, the teachers did not engage with holders of IK in museums, as in the case of 3-day-long SLPs). On day one (for the first two SLPs), participating teachers visited museums in Polokwane (Bakone Malapa) and Moruleng, near Rustenburg (Mphebatho Museum), and had the opportunity to meet with the holders of IK (see Figure 6.1).

During the first day, participating teachers were exposed to exhibitions and discussions about different aspects of IK, such as ethnobotany, sustainable use of water by their ancestors and traditional leather tanning. They were also engaged in brewing and tasting traditional beer, made clay pots, ate traditional delicatessen like mopane worms, did drumming and played traditional games such as *Morabaraba*. Engagement with all these activities placed these teachers in an IKS epistemological space and contributed to their true understanding of the NOIK and the different cultural practices of the Bakgatla and Bafokeng tribes. Because of time and financial constraints, the visits to the museums were excluded from some of the SLPs.

Days two and three of the three-day SLPs, and days one and two for the rest, were used to expose the teachers to the use of different engaging pedagogies, such as CL, PBL, inquiry learning, science-on-a-shoestring and contextualised learning approaches. The purpose of the intervention was to contribute to these teachers' better understanding of the NOIK and the NOS, in order for them to get rid of any misconceptions and their initial understanding that the NOIK and the NOS were two opposing concepts. The activities conducted during the SLP exposed teachers to methods that can be used where the NOS and NOIK can complement each other in the science classroom. All activities over the 3-day period were done using CL (see Figure 6.2), as described by Johnson and Johnson (1994).

During all CL activities, efforts were made to explore the different elements of CL. The CL methods used were the jigsaw



Source: Photograph taken by Josef de Beer, exact date and location unknown, published with permission from Josef de Beer.

FIGURE 6.2: Teachers engaging in CL during the Northern Cape intervention.

method and De Bono's five thinking hats. In order to expose the teachers to the use of contextualised science teaching, one of the activities, based on inquiry learning principles, was to design and execute an experiment in testing the healing effects of traditional plants (ethnobotany). In this regard, the participating teachers executed this inquiry-based experiment (an adapted Kirby–Bauer experiment) in a real laboratory (see Figure 6.3). The researchers assumed that working in a 'real' laboratory, facilitated by a microbiologist, will make the teachers aware and expose them to a more nuanced understanding of the NOS. This experiment also covered the tenets of science such as its creativity and that it is socially constructed. In another activity, also based on a contextualised science teaching approach, teachers were trained in using case studies as a form of PBL in designing teaching–learning activities for their learners.

Source: Photograph taken by Josef de Beer, exact date and location unknown, published with permission from Josef de Beer.

FIGURE 6.3: Teachers engaging in the Kirby–Bauer technique, to test the antimicrobial effects of *muthi* plants, in a laboratory during the Limpopo intervention.

Ethics

In cooperation with the different departments of basic education in the different provinces, an open invitation was given to all science teachers who wished to participate in the SLP. As part of the invitation, all information regarding the intervention was provided to prospective participants in order to make voluntary informed consent to participate or not in the research. They were given the assurance that their participation in the research would be voluntary, that they did not have to complete the data instruments even if they participated in the intervention, or made themselves available for observation in their classes. Ethics clearance was obtained from NWU. The science teachers were also informed that they could withdraw from the research at any stage without any negative consequences and that their identities would be protected during the reporting phase of the research using pseudonyms. Teachers signed model release forms that provided permission to publish photographs in which they appear; however, we have blurred their faces in the photographs used in this chapter.

The following data gathering instruments were used during and after the intervention:

- Pre- and post-questionnaires (perceptions of the NOIK, perceptions of the NOS and a questionnaire to determine teachers' perceptions of their knowledge and skills regarding PBL).
- Both individual and focus group interviews were performed during the SLP and during school visits.
- School visits to observe participating science teachers in their classes to determine if transfer of knowledge and skills, gained during the SLPs, did occur. The standardised Reformed Teaching Observation Protocol (RTOP) (Sawada, Piburn & Judson 2002) was used for this purpose.
- Artefacts, such as teachers' lesson plans and reflection notes, were studied.

Transana and Atlas.ti were used to analyse the qualitative data (transcriptions of interviews, RTOP, artefacts). Data were analysed using Saldaña's (2009) coding system where codes were identified, categories formed and from which a number of emerging themes could be identified.

Analysis of views-on-the-nature-of-indigenous-knowledge instrument data

Views-on-the-nature-of-indigenous-knowledge (VNOIK) data were analysed using the method described by Cronje, De Beer and Ankiewicz (2015:328). A rubric was used to assess the answers of respondents to the instrument items. Each response was (Cronje et al. 2015):

> [*C*]oded as an informed view (I), a partially informed view (PI) or an uninformed view (UI) on indigenous knowledge. An uninformed view scored 0 points, a partially informed view scored 1 point, and an

> informed view scored 2 points. The predominant category for each teacher was obtained by calculating the average. (p. 328)

In order to improve the quality of the interventions in consecutive SLPs, different design principles were distilled. In the first cycle, 62 teachers participated, but only 34 submitted their portfolios, of which only 24 portfolios obtained a pass mark of 50%. In order to improve the submission rate, participating teachers in the second and third cycles were encouraged to do the submissions online, in hard copy and/or in smaller parts. Only a few teachers made themselves available for visits in their classrooms, and it was found that in most cases transfer of knowledge and skills did not take place. In some instances, the teachers that were visited indicated that a lack of resources contributed to them not using the newly acquired teaching–learning methods. In cycles 2 and 3, teachers were also provided with science-on-a-shoestring resources to be used in their classrooms. These resources included a fold scope (a paper microscope having a magnification of up to 2000x costing only $1, resources to do the Kirby–Bauer test in the classroom, an optics kit, kit to test for water quality, etc.). Going hand-in-hand with the provided resources, teachers were also exposed to the use of more common products such as garlic and turmeric in the Kirby–Bauer tests and to use the examples of different cultural and racial groups. For instance, a tailor-made SLP was offered in Lenasia, with a broader focus than just African IK, but also incorporating Ayurveda (Indian IK), in contextualising CAPS themes. Yet another design principle built into the follow-up interventions was exposing participating science teachers to the use of CAR. This design principle was included because it was found that the low pass rate on the portfolios in the first cycle was owing to the fact that the participating teachers did not possess good reflection abilities. It was hoped that such an addition would develop participating science teachers' reflective practices. A 'one-size-fits-all' approach does not work, and in the third cycle, participating teachers' needs were identified in order to change the content of the SLPs accordingly to serve the specific needs of these teachers.

Reliability was ensured by using suitable and thorough data collection strategies contributing to the thoroughness of the data obtained. Multiple data sources were used for triangulation purposes over an extended period of time. Triangulating the different data sources contributed to the trustworthiness of the research. The findings of this research cannot be generalised, however, but if the same methodology were used in similar environments, it might deliver comparable results. Onwuegbuzie, Johnson and Collins (2009) refer to this type of generalisation as case-to-case transfer. According to Shenton (2004), the purpose of such a study should not be to get the same results, but rather to get an overall picture of the phenomenon or group of people under study.

Findings and discussion

The main goal of the research reported in this chapter was to determine how engaging pedagogies could be used to facilitate border-crossing between the NOIK and the NOS. Numerous data sources were analysed, and several themes arose from the data analysis. These themes will be discussed in the following paragraphs. The first part of the discussion will deal with the findings made regarding engaging pedagogies that were used during the intervention. Thereafter, the discussion will reveal to what extent engaging pedagogies have contributed to the epistemological border-crossing between NOIK and NOS.

Findings with regard to cooperative learning

With the onset of the intervention, participating teachers had limited knowledge of CL, but after the intervention there was an improvement in their knowledge about CL and how to implement it.

Before the intervention (data from the pre-questionnaires), teachers' responses varied between very little knowledge about CL to some teachers who seemingly had a superficial understanding of the term, but many confused CL with traditional group work. One teacher commented, '[n]ot really well informed. Still need support. I do improvise where necessary' (cited in Jacobs 2018:128). Many teachers were aware of group work as a method to facilitate learning and many used it. However, group work, as the participating science teachers understood it, is not the same as CL. Cooperative learning, as described by Johnson and Johnson (1994), can only be successful if all five elements mentioned earlier are present during the learning experience while group members work together to reach a common goal. One participant stated, '[v]ery familiar [CL], but I know it as group work' (teacher, undisclosed gender, date unknown). Another participant was not aware of the term CL itself, but knew that the notion of 'cooperative' signified 'people working together in small groups' as he or she wrote, 'has to do with group work, teamwork where the teacher direct, but learners work on their own' (teacher, undisclosed gender, date unknown). It can thus be deduced that many teachers were not aware of the term themselves, but that they knew that the term 'cooperative' indeed refers to people who work together in small groups or teams. Some teachers structured their group work on the principles of the jigsaw method but were unaware of the term 'jigsaw'. 'I often administer it, it [is] just that I was not familiar with the jigsaw model of cooperative learning and the De Bono hats' (Jacobs 2018:131).

Based on the responses of the participating science teachers in the post-questionnaires, it can be inferred that their knowledge and comprehension about CL did improve. What half of the participants wrote in the post-questionnaires supports this finding. 'After the intervention, I clearly understand that cooperative learning involves different teaching methods such as the jigsaw method and the De Bono's Hats method' (cited in Jacobs 2018:129). Another teacher stated that 'at first I did not know what it was and it is only now after attending the course that I understand it' (cited in Jacobs 2018:129), and yet another response was that 'learners should be able to learn cooperatively as a group, be able to share ideas to achieve positive interdependence' (cited in Jacobs 2018:245). One question on the post-questionnaire was: Did this short course change your views on the use of CL methods in the Life Sciences classroom? Of all the teachers who completed the generic questionnaire, 59.68% indicated that the SLP changed their perceptions on CL positively. A further 40.32% said the SLP brought about a change in their perception of CL.

Three months after the intervention, all science teachers who attended the SLP were requested for consent to visit them at their schools to observe a lesson and to study their artefacts (lesson plans, reflection notes and learners' workbooks). Only four of the 75 teachers that attended the Limpopo workshop availed this opportunity. After the intervention in Lenasia, only five participating teachers gave consent to be observed. The RTOP instrument was used for the observations. Although a large group of teachers (59.68%) indicated that, after the intervention, they had a better understanding of CL, the observations showed otherwise. In not one of the lessons observed, it was apparent that the teachers possessed adequate skills to design and present elective CL lessons. The five basic elements of CL were not evident during the lessons. However, we need to mention that the environment was not conducive to practice CL, as the classes visited in the Limpopo schools were overcrowded with learners, and in some classes, there were not enough tables and chairs. There is a discrepancy between knowledge and skills in the use of CL. Reddy (2019) found that regardless of the teacher development programmes that the teachers attended, they continued to teach in the manner in which they were taught. The teaching approaches remained teacher-centred with little evidence of the use of inquiry techniques. The fact that the furniture in most of the classes was arranged in a manner that made CL difficult to implement should be acknowledged. The teachers mentioned a number of reasons for the non-use of CL; this will be explained later in this chapter.

Findings with regard to problem-based learning

At the onset of the intervention, participating teachers had limited knowledge of PBL, but after the intervention there was an improvement in their knowledge about PBL and their attitude towards implementing PBL.

The data reported in the pre-questionnaires indicated that although some of the participants possessed knowledge about PBL, most of them had very little or no knowledge about PBL. Most of the teachers also indicated that they did not know how to implement PBL and therefore refrained from using it as a teaching–learning strategy. Some of the comments of the teachers support this finding (cited in De Villiers 2018):

> 'I do not know what problem-based learning is'; 'I read about it before, but I was not fully engaged with it'; 'It's better to explain the work to learners, I don't like doing things in class where learners just do what they want'. (p. 324)

Reading the last comment made by one of the science teachers, we can also conclude that this particular teacher was stuck with using only transmission-mode teaching–learning methods. In this regard, So and Kim (2009) contended that, although some teachers had basic knowledge about PBL, the knowledge was not sufficient to introduce PBL as they were not able to manage learning experiences in a correct way.

The post-questionnaires showed that 59 of the 62 teachers (95.1%) who completed the questionnaire gave an indication that they had a better understanding of PBL after the SLP and that they would also use it in their lessons. One of the teachers commented, 'I have learned that problems from learners' environments will enhance learning' (cited in De Villiers 2018:145). Another teacher stated that 'problem-based learning makes the learners think and work instead of the old method of teaching of just writing on the board. I want to use it' (cited in De Villiers 2018:263). Another teacher gave an example of how PBL may be used in a Life Sciences learning experience, saying '[g]ive them a problem, for example global warming, and expect them to come up with a solution based on the given problem' (cited in De Villiers 2018:243). Based on the comments of some teachers, we can also conclude that they understood the teachers' role as a facilitator during a PBL lesson, for example, when they said 'PBL looks at real-life problems, the teacher facilitates learning and expecting the learners to actually be problem-solvers' (cited in De Villiers 2018:125).

From the findings of this study – with comments such as 'I'm definitely going to apply it [PBL] in my class' (cited in De Villiers 2018:262) and 'A more learner-centred approach, as a facilitator you also learn from learners' (cited in De Villiers 2018:145) – it was clear that the intervention had positively influenced the participating teachers' knowledge and PCK with regard to the implementation of PBL. However, the observations made during the class visits in Polokwane (Limpopo) revealed that although teachers gained from attending the intervention, they failed to use it in their classes. The teachers observed mentioned a number of reasons that will be elaborated on later in this chapter.

It is necessary to provide additional support to these teachers in the implementation of PBL and IK to ensure the facilitation of border-crossing between the tenets of science and IK.

In Chapter 2, Mentz and De Beer focus on data regarding PBL after the Calvinia intervention. Sufficient evidence was provided that PBL was better achieved during this intervention.

Findings with regard to the nature of indigenous knowledge and the nature of science

At the onset of the intervention, participating teachers had limited knowledge of the NOS and NOIK, but after the intervention there was an improvement in their knowledge about IK and the NOS and their attitude towards infusing IK into the science curriculum.

Literature showed that teachers usually do not have a nuanced understanding of the NOS. At the beginning of the SLP, most of the participating science teachers strengthened this finding by referring to the NOS as, 'scientific method using empirical methods of investigation' and 'result-oriented; process of discovering; practical investigations'. The comments made by the participants do not recognise the creative, subjective and culturally embedded tenets of the NOS. Reddy et al. (2018) argue that if teachers do not have a nuanced understanding of the NOS, the NOIK will also be unclear, leading in turn to an inability of science teachers to integrate IK in the science content.

In a master's study conducted by De Villiers (2018), a postgraduate student in this funded IK project, the data of the VNOIK pre- and post-questionnaires were used to categorise the participating science teachers' (*N* = 83) knowledge of IK as uninformed, partially informed or informed. The study reported that 12% of teachers were uninformed, 86.67% partially informed and only 1.33% had knowledge about IK. Comments from the teachers during the interviews and on the questionnaire include 'I didn't have this knowledge on IK. I didn't even think about it' (cited in De Villiers 2018:154). Another teacher commented that 'I just stick to the curriculum. I just teach theory from text books' (cited in De Villiers 2018:324). Reddy (2019), prior to the SLP, reported that 87% of teachers were uninformed about IK and afterwards almost the same percentage indicated that they had an informed view.

Some teachers had misconceptions about IK and, therefore, did not care to infuse IK into the curriculum; '[a]t the beginning I had a misconception that indigenous knowledge means witchcraft and *muthi'* (cited in De Villiers 2018:324). Another participant from the Lenasia also alluded to a misconception that IK only refers to African IK (cited in De Villiers 2018):

> So when I saw that there is Indian and Dutch etc. IK, I thought this is interesting; I was living in my own world. I thought it was only the Zulu traditional medicine that exists. So yes, it opened my mind. (p. 324)

Twenty per cent of the participants who attended the Lenasia SLP (*N* = 15) said that there was no way to verify IK. This of course also indicates a misconception because the healing effects of traditionally used plants can be tested in a laboratory as is done with the Kirby–Bauer process during the SLP. In another example, presented as a PBL approach, the participating teachers were presented with two problems about the role of ethylene in seed germination and the role of ethylene in the post-harvest physiology of cut flowers (flower senescence). The investigation about germination of seeds was contextualised by the Chinese practice of burning incense to release ethylene to enhance the ripening of fruit (De Beer & Petersen 2017a). The other investigation pertained to prolonging the shelf life of cut flowers. This can be linked to, firstly, Dutch IK and also local IK according to which coke, sugar, bleach, etc. can be used to prolong the shelf life of flowers (De Beer & Petersen 2017b). Both these problems can be investigated in the laboratory, facilitating the border-crossing between the NOS and the NOIK. Another comment indicated that although some teachers realised the value of infusing IK into the curriculum, they did not have sufficient PCK to do so, stating that 'although I see the value of IK, I do not know how to bring it alive in my classroom' (cited in De Villiers 2018:324). Even though the participating science teachers who attended the SLP in Lenasia were well qualified to teach Life Sciences, most of them did not integrate IK or use it to contextualise the science content. One teacher indicated that the topics of the nervous system, gaseous exchange and photosynthesis were not suitable to infuse IK into the lesson (Reddy et al. 2018). This comment is a clear indication of this teacher's insufficient PCK with regard to IK because human diseases, as part of human physiology, can easily be linked to local practices in treating diseases.

Findings with regard to the nature of indigenous knowledge

In most of the interventions listed in Table 6.2, we had pre-VNOIK questionnaires for all participants, but unfortunately only some of the teachers submitted the post-VNOIK instruments with their portfolios after the SLP. For this reason, it is statistically more meaningful to show the overall picture (for all the interventions), comparing respondents' (for which we have both questionnaires) performance in the pre- and post-VNOIK instrument. Our data support the findings of Cronje (2015) and De Beer and Mentz (2016), who have shown that the SLP in general has a positive influence on teachers' learning and that, in the post-VNOIK questionnaire, teachers generally express more nuanced views of IK, as can be seen in Table 6.3.

One of the questions during the interview to the participating teachers was: After completing this SLP, will you integrate IK into your teaching? Some of the answers of the respondents were '[d]efinitely. I've learned how to use the things that I have to teach learners about indigenous knowledge' (cited from De Villiers 2018:326) and 'I think it's part of us and it's very important [...] Indigenous knowledge to me is the same as science. Why don't we teach it in school?' (cited in De Villiers 2018:154). These reactions of the participating science teachers give an indication of their attitudes towards infusing IK change positively. The remarks made by two of the teachers also attest to the fact that their knowledge about IK and how to infuse it into the curriculum had improved, stating that 'the fermentation process, making beer and the preservation of food, those methods can be linked to the curriculum' (cited in De Villiers 2018:326), and 'an activity can be designed where learners do research on how elders would heal infections' (cited in De Villiers 2018:326). The data collected during the Lenasia intervention further supported the finding that the SLP contributed to improving the participating science teachers' PCK with regard to IK.

TABLE 6.3: Teachers' performance in the pre- and post-questionnaire (all cohorts of teachers referred to in Table 6.2).

View of participants	Percentage in the pre-questionnaire (prior to intervention)	Percentage in the post-questionnaire (after intervention)
Uninformed view	4.5	0
Partially informed view	78.5	54.5
Informed view	17.0	45.5

Challenges in using engaging pedagogies and indigenous knowledge in science education

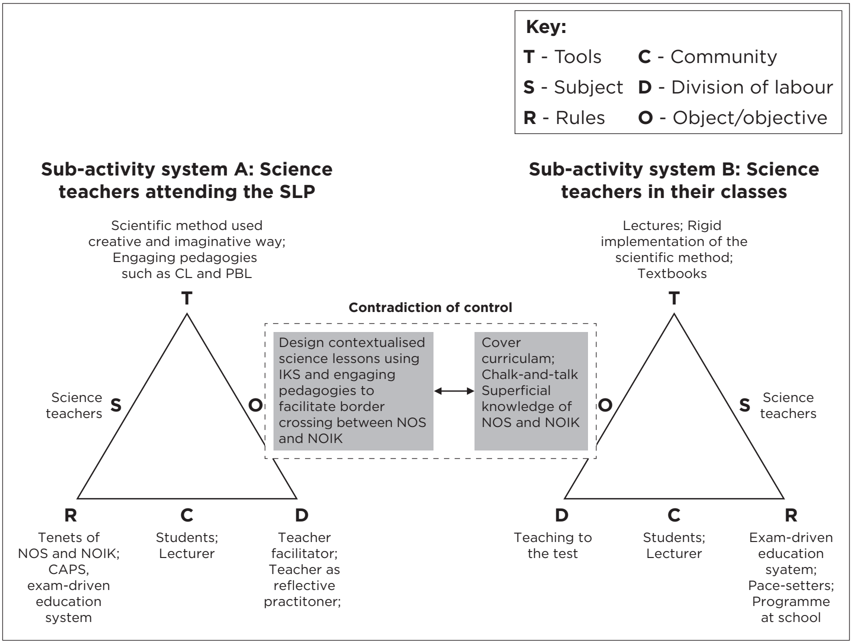
In spite of the overwhelming positive responses, experiences and improved PCK of the participating science teachers in the SLP, most of those observed could not transfer the newly learnt knowledge and skills into actual practice. So why did transfer not take place in the classroom? Why is it that teachers struggled to design teaching–learning experiences where the science content can be better contextualised in order for learners to identify with the content taught? This is necessary for learners to, firstly, learn on a social plane with others and, secondly, to internalise it on a personal plane in the ZPD.

Lortie (1975) gives one reason for why teachers do not change their practices, in what he calls the 'apprenticeship of observation', which he explains as the practice whereby teachers base their own practices on knowledge gained by observation, imitating their own teachers while they were in school. The reality in most South African science classes is therefore the continuation of using predominantly transmission-mode teaching–learning methods.

Zeichner and Tabachnick (1981:7) provide another reason for this phenomenon, where teachers failing to apply what they learnt at university (or after SLPs) can be explained by the 'wash-out effect'. This happens when skills and knowledge learnt during teacher development courses 'are often "washed out" at the coalface of teaching in the classroom' (De Beer & Mentz 2018:7). In Chapter 3, De Beer and Mentz refer to teachers' inclination to use transmission-mode approaches and 'teaching-to-the-test'. The same authors argue that teachers are caught up between the demands of the university and schools. The demands of schools refers to the systemic pressures or rules regarding covering the curriculum at all costs, following pace-setters in time, and the examination-driven system forcing teachers to teach to the test.

Findings through the Cultural-Historical Activity Theory lens

The data indicate that the SLP did improve the participating science teachers' PCK with regard to using engaging pedagogies, such as CL and PBL, and IK to contextualise the science content in order to facilitate border-crossing between NOS and NOIK. The findings reported in this chapter are also supported by a number of other studies in this funded project (De Villiers, De Beer & Golightly 2016; De Beer & Mentz 2018; De Villiers et al. 2018; Jacobs, De Beer & Petersen 2016; Reddy, De Beer & Petersen 2016, 2017; Reddy et al. 2018; White & De Beer 2017). In Figure 6.4, the left activity system represents the science teachers' (subject) professional development with the SLP. While reaching the object during the SLP, teachers were trained to act as facilitators of



CL, cooperative learning; PBL, problem-based learning; NOS, nature of science; NOIK, nature of indigenous knowledge; CAPS, Curriculum and Assessment Policy Statement; SLP, short learning programme.

FIGURE 6.4: Third-generation CHAT.

learning and to be reflective practitioners (division of labour). One of the design principles of the second and third cycles of the DBR was to expose participating science teachers to the use of CAR in order for them to improve their teaching–learning practices. Guided by the rules in the activity system, namely, all the tenets of NOS and NOIK (see Table 6.1), and in spite of the examination-driven education system, teachers used the engaging pedagogies in such a way as to infuse IK into the science content during the SLP. This empowers teachers with a nuanced understanding of the tenets of the NOS and NOIK, to facilitate the border-crossing between the NOS and NOIK. The newly learnt knowledge and skills enable participating science teachers to design contextualised teaching–learning experiences for their learners, in line with Gibbons' (2000) Mode 2 knowledge production.

CL, cooperative learning; PBL, problem-based learning; NOS, nature of science; NOIK, nature of indigenous knowledge; CAPS, Curriculum and Assessment Policy Statement; SLP, short learning programme.

The juxtaposed activity system, on the right-hand side of Figure 6.4, represents the activity system of the same science teachers who attended the SLP in their classes after the intervention. The data collected during the observation and the artefacts studied indicated that most of the teachers observed, in spite of their positive experience of the SLP, failed to introduce engaging pedagogies in their classes to infuse IK into the science content. We can therefore argue that although the border-crossing between NOS and NOIK did take place in an academic or a cognitive way, it did not take place in practice. We can further argue that there exists a tension between the objectives of the two activity systems. The object in sub-activity system A (Figure 6.4) favours having teachers design contextualised science lessons using IK and engaging pedagogies to facilitate a border-crossing between NOS and NOIK. On the other hand, the object in sub-activity system B shows teachers going back to the olden ways of using predominantly teacher-centred methods, also referred to as 'chalk-and-talk', when covering the curriculum content (refer to the research of Ramnarain and Schuster 2014). If the teachers do practical work, most follow the scientific method in a superficial way, not attending to all the tenets of the NOS and NOIK (Table 6.1). Most participating science teachers follow these methods in spite of the CAPS document, which requires teachers to use IK when teaching science content. The reason for these practices of teachers is the exam-driven education system, which expects teachers to follow the pace-setters to cover the curriculum in time. Zeichner and Tabachnick (1981:7) argued that the teachers are 'caught between the conflicting demands exerted by the schools and universities' (read also professional development SLPs).

■ Recommendations

Science education should deliver learners who experience the relevance of science in their everyday lives and who have a good understanding of the NOS in order to be scientifically literate individuals. Such individuals will be in a better position to participate effectively in the 21st century society and make informed choices in their day-to-day lives. In order to foster such learners, we need competent science teachers possessing good PCK. The SLPs presented to science teachers, as described in this chapter, aimed at contributing to science teachers' PCK in order for them to be agents of change in their schools and classrooms. The findings of this research indicate that the SLPs were only partially successful in so far as they did add value to the participating science teachers' knowledge and skills with regard to engaging pedagogies and infusing IK into the curriculum, but were not so successful in terms of transfer of knowledge and skills of most of the teachers observed, which did not take place. Although design principles of previous SLPs were identified and incorporated into subsequent SLPs, it is still necessary to identify additional design principles that could further inform and adapt future SLPs. Improving SLPs, notwithstanding the systemic pressures that teachers experience, might contribute to science teachers' ability to apply the newly learnt skills in their classrooms. One such design principle in this DBR can be to customise a specific SLP to cater to the specific needs of the particular participating teachers. A thorough needs analysis of the prospective participants should be performed to inform the adaptation of the contents of the SLP. One shortfall of the intervention described in this chapter is that, post-intervention, the participant teachers did not always have access to the researchers. This was because of not only time constraints experienced by researchers but also a lack of assisting the CoP established during the SLP. The CoP established during the SLP should function more effectively in a sustainable manner. In order to enhance the effectiveness of the CoP, a few teachers attending the SLP should be identified by the researchers to take a leading role in the CoP. Such leading teachers should be passionate about science teaching, possess good PCK, have an aptitude to work with people and social media, and be agents of change in spite of systemic pressures. Wenger (2006) refers to such leading teachers as the keystone species, absolutely necessary to the effective and continuous functioning of a CoP.

At the beginning of this chapter, we referred to Vision 2030 envisioning the eradication of poverty and the need to make education more accessible to the marginalised. We believe that the work done with science teachers as reported in this chapter does contribute to the activation of Vision 2030 by adding value to the professional development of science teachers, empowering them to use engaging pedagogies to design contextualised science teaching–learning experiences accessible to most South African learners.

Summary

Science education in South Africa is characterised by predominantly teacher-centred teaching and learning approaches where the subject content is usually not well contextualised. Where practical work is done, it is characterised by the steps of the scientific method, emphasising the empirical NOS, but marginalising tenets such as the creative NOS. This practice leads to learners not having a nuanced understanding of the tenets of the NOS. This chapter reports on research on the affordances of IK not only as a vehicle to contextualise the science content but also to facilitate border-crossing between the tenets of the NOS and the NOIK. In this regard, Gibbons (2000) refers to context-sensitive science as Mode 2 knowledge production to address the usually neglected affective domain in science teaching. Both the NOS and the nature of IK include socially and culturally constructed tenets of an empirical, inferential, tentative, subjective and creative nature. The research question addressed in this qualitative study was: How can engaging pedagogies facilitate the epistemological border-crossing between (the tenets of) science and IK? The authors define engaging pedagogies as any inductive teaching–learning strategy such as PBL, CL or contextualised learning, where the learners or students are actively involved in the learning process while developing 21st century skills. Learning methods purposefully focus on the development of affective outcomes. Third-generation CHAT was used as an analytical lens to get a theoretical grasp of the research data collected on a SLP for science teachers and to identify tensions in the activity system. Teachers do not have nuanced understandings of the NOS and the NOIK and are therefore not in a position to design appropriate teaching–learning experiences for their learners to understand these concepts. This chapter reports on the findings based on the data collected during the SLPs presented to science teachers where they were exposed to ways of integrating the tenets of the NOS, IK, PBL and CL. The data indicated that IK, through engaging pedagogies, can be used to facilitate the border-crossing between science and IK.

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Chapter 7

The affordances of indigenous knowledge in Mathematics Education

Marthie van der Walt[a,b]
[a]School of Mathematics, Science and Technology Education, Faculty of Education, North-West University, Potchefstroom, South Africa
[b]Research Unit Self-Directed Learning, Faculty of Education, North-West University, Potchefstroom, South Africa

Erika Potgieter[a,b]
[a]School of Mathematics, Science and Technology Education, Faculty of Education, North-West University, Vanderbijlpark, South Africa
[b]Research Unit Self-Directed Learning, Faculty of Education, North-West University, Vanderbijlpark, South Africa

Divan Jagals[a,b]
[a]School for Professional Studies, Faculty of Education, North-West University, Potchefstroom, South Africa
[b]Research Unit Self-Directed Learning, Faculty of Education, North-West University, Potchefstroom, South Africa

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Introduction

In a rapidly changing world, and a complex 21st century, teachers' teaching–learning activities need to adapt to the changing needs posed by a globalised world, which means learners need to be equipped with workplace skills for future jobs that could be demanding (Davidson 2012; Portilho & Medina 2016; Smith & Morgan 2016). Traditional Mathematics teachers' transmission-mode teaching–learning of the Westernised (abstract, decontextualised) curriculum needs to be reconsidered, as it seems to fail to develop in learners the ability to reason mathematically (Boaler 2015). Furthermore, achievement and interest in Mathematics among South African learners are low. Mathematics is widely despised and regarded as a boring subject accompanied by an aversion for Mathematics (negative emotions). Mathematics, therefore, becomes a subject that involves 'a set of procedures to be followed' by learners, parents and some teachers, creating a negative attitude towards it (Brodie 2016a). There are but a few teachers who have not heard learners say 'why do I have to learn Mathematics? I'm never going to use it!'

Against this backdrop, current trends in Mathematics Education research focus on the investigation of mathematical ideas and practices (contexts) that occur outside the school classroom (Rosa & Orey 2013). The infusing of IKS serves as a methodology to fuse Mathematics and culture together. Research shows that learners have cultural knowledge and experiences that support them in their learning endeavours (Furuto 2014). When compared with Western Mathematics, teaching with IK brings about several differences in the learning experience. The first difference lies within the way knowledge is transmitted. Indigenous knowledge is transmitted orally, while Western Mathematics is mainly written. Also, IK is based on real-life observations and experiences, evaluated in the light of what one has learnt from elders, whereas Western Mathematics is taught and learnt often (not always) in an abstract context (Anonymous n.d.).

Teaching Mathematics only in a Western context ignores the value learners experience from the subject, as it overlooks the link between content, curricula and real life, and diminishes meaningful learning of Mathematics. As Mathematics belongs to all cultures, stemming from different needs, the goal remains the same: to develop and empower (Ndlovu 2018; Salami & Okeke 2017).

■ Problem statement

South Africa is situated within a multifaceted ethnic, racial and cultural setting. The rich cultural IKS that can be referred to as 'knowledge in the blood' includes views, values and attitudes related to cultural practices (Webb 2011). Although South African education has experienced many curriculum reforms since 1994, the quality of teaching and transformation has not yet improved as envisaged (Tsotetsi & Mahlomaholo 2015). The National CAPS of South Africa clearly states that IKS should be acknowledged with regard to the rich history and heritage it encompasses (DBE 2011).

While the value of IK in education has been well recognised, this recognition has not yet been translated into implementation of the school Mathematics curriculum (Luitel 2013), especially in South Africa. In the Mathematics classroom, the teacher should make use of and incorporate learners' own ideas linked to their IK and culture, which should be linked to Mathematics (Baturo, Norton & Cooper 2004). In addition, the lack of nuanced PCK among some teachers and the limited quality teacher professional development in South Africa, particularly regarding IK, are a cause for concern (CDE 2011). Teachers who are unprepared or underprepared for teaching–learning practices, or those who are ignorant of the views, cultural practices, beliefs, values and attitudes possessed by our learners, will not be able to meet this demand. Consequently, if they do not apply contextualised Mathematics because of the lack of adequate training and implementation, both content and pedagogy would suffer.

Research question

The research question that guided this research is: What are the affordances of IKS for a teacher professional development intervention in which Mathematics topics are contextualised in indigenous games, music and puppetry using the PoP (and using metacognition as reflective methodology)?

Theoretical framework

As a cultural lens through which Mathematics can be viewed in order to enrich the teaching and learning experience for learners in the classroom, indigenous games, like *Morabaraba* and *Ncuva*, can form an integral part of ethnomathematics and provide an opportunity to contextualise Mathematics topics in IK (Nkopodi & Mosimege 2009). As soon as the nature of learning is influenced by the environment in which it takes place, contextualisation occurs (Brown 2008).

Horsthemke and Schäfer (2007) are not convinced that ethnomathematics facilitates access to 'real' Mathematics in the South African context — it is only meaningful in a very narrow localised context. They question the challenge to locate and identify scientific skills, knowledge and processes embedded in cultural practices in order to simply redesign and reformulate present curricula. However, these authors admit that current research is too scant to show that the general concept (of contextualising Mathematics in IK) actually works. A weakness with their argument, however, is that the teacher who acts as the 'agent of change' in the classroom is responsible to bridge the gap between mathematical content and enculturated (contextualised and mathematised) content in such a way that learning becomes meaningful for learners in the Mathematics classroom. The most recent research to date has tended to focus on ethnomathematics as a 'gateway' for inclusion. An advantage of ethnomathematics for teachers and learners is that it leads to social interaction and collaboration. Social interaction regulated by the teacher when implementing ethnomathematics approaches is important because it leads to a better understanding of each other's culture and real-life experiences (Zevenbergen et al. 2010).

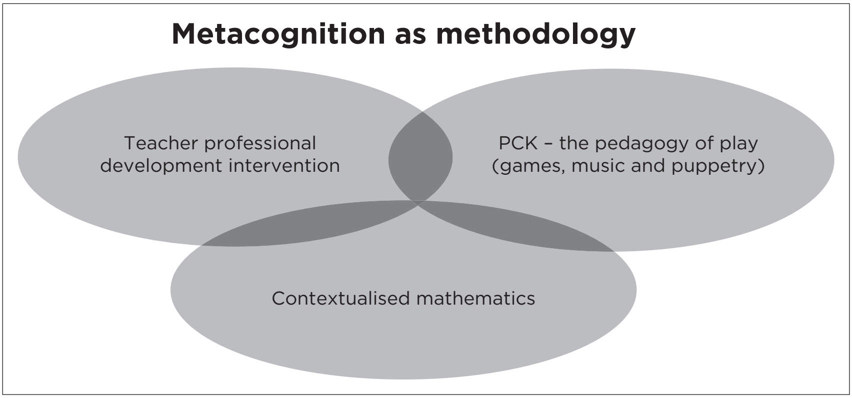
Therefore, the theoretical framework that provided the foundation of this research is social constructivism as conceptualised by Vygotsky (1989). Social constructivism (which stems from constructivism) emphasises cognitive growth in teaching–learning endeavours, which allowed participants in the intervention to socially collaborate – in this case, the PoP – to explore indigenous games, music and the use of puppetry to enhance teaching–learning in Mathematics (Amineh & Asl 2015). Social constructivism allowed us to describe the affordances of contextualising Mathematics in IK according to participants' perceptions and experiences with PoP and indigenous games.

Conceptual framework

The need for literature in a South African professional teacher development context suggests that teachers should be introduced to Mathematics topics or themes contextualised in IK or learners' everyday lives. The elements in Figure 7.1 will subsequently be discussed under the conceptual framework of this study.

Metacognition as reflective methodology

Flavell (1979) defined metacognition as metacognitive knowledge and self-regulation. In order to be responsible for one's own lifelong learning or professional development, one needs to be consciously aware of one's thinking when orchestrating one's own teaching–learning by taking action when teaching and/or learning. The tendency to think about a teaching task (producing a metacognitive conceptualisation of the task) and to use metacognitive knowledge and self-regulation is called reflection (Cornoldi 2010; Ertmer & Newby 1996).



PCK, pedagogical content knowledge.
FIGURE 7.1: Metacognition as reflective methodology.

Metacognition as reflective methodology was used in this research to enhance and deepen teachers' learning experiences during and after the SLP and to support them in transferring their new PCK (PoP) and knowledge about contextualised Mathematics to their classrooms. Reflection emerges as a way of supporting teachers' improved understanding of what they know and do, as they develop their knowledge of teaching through reconsidering what and how they teach (and how their learners learn). Reflection develops understanding about the way teachers conduct their work and focuses on their understanding of the (teaching–learning) task, strategies and about themselves, constructing connections between prior and new knowledge about teaching–learning practices or activities.

Metacognitive knowledge of cognition

One becomes aware of one's current state of accomplishment along with the situational influences and strategic choices that are currently influencing or which have previously influenced the accomplishment of that process through reflection (Scharff 2015). Reflection on metacognitive knowledge precedes, accompanies and follows cognitive strategies (Livingston 2003);

teaching–learning content (subject matter), on the one hand, and metacognitive knowledge (person, task and strategy variables) and self-regulation (planning, monitoring and evaluation) on the other.

Reflection is seen as the intentional, ongoing interaction between metacognitive knowledge and self-regulation of the development of teaching–learning processes. Metacognition – through reflection for (before), in (during) and on (after) teaching and/or learning – is the medium through which we teach and learn by planning, monitoring (guiding) and evaluating teaching and learning (Cornoldi 2010). Such reflection is the link between metacognitive knowledge used to oversee and regulate teaching–learning and understanding through predicting outcomes, planning activities, monitoring activities and checking outcomes of the activities, ensuring that the cognitive goal has been met. When in need of appropriate teaching–learning strategies, the teacher must think about similar experiences or problems and reflect critically on these to differentiate between the available and appropriate approaches.

Self-regulation (or regulation of cognition)

Actions that arise from intentional thinking are deliberate, informed and goal-directed and refer to control processes such as self-regulation of one's thought process.

Metacognitive awareness refers to the conscious awareness in planning, control or monitoring, and evaluation of one's own cognitive processes (Sternberg & Sternberg 2012:234). Teachers who are metacognitively aware of their Mathematical Knowledge for Teaching (MKT) are able to predict or even avoid misconceptions and errors; are more rigorous in their explanations of school Mathematics, deepening learners' knowledge on topics; provide environments for a rich discussion pertaining to the curriculum content; and are able to implement and critically reflect on the curriculum so as to select the best resources to assist in the contextualisation of lessons (Ball, Thames & Phelps 2008).

Furthermore, self-regulation is an active part of planning and prediction, monitoring and evaluation (Bransford, Brophy & Williams 2000; Dunlosky & Metcalfe 2009).

Planning refers to how a teaching–learning task is approached, thinking about the teaching objective and available time, selecting and using appropriate skills and strategies to teach the topic, self-assessing which type of task is at hand, goal setting, responding to what the task requires and what one wants to achieve, who is acting and how one would approach the task.

Prediction skills include the selection of appropriate strategies and allocation of resources (Desoete 2008). This skill enables a teacher to predict the difficulty of the (teaching and/or learning) task and to use that prediction to regulate the engagement related to the outcome. According to Savin Baden and Wilkie (2004), teachers must diagnose their own and their learners' learning needs and identify resources for teaching–learning.

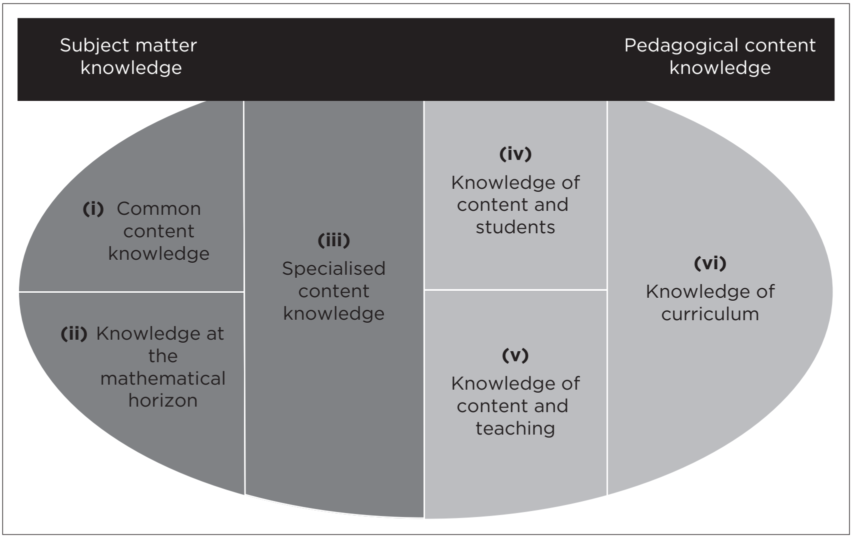
Monitoring refers to one's continued awareness of comprehension and task performance through monitoring one's own and others' (e.g. learners') comprehension of text, progress towards completing the task or solving the problem, self-assessing and self-correcting responses to self-assessment, understanding personal achievement through continuous monitoring of the progress one has made towards the cognitive goal and becoming more aware of distracting stimuli (Dunlosky & Metcalfe 2009).

Evaluating the results of one's teaching–learning efforts (i.e. approaches and strategies used to complete the task) improves one's awareness of effective teaching–learning strategies and skills and provides ways to use these strategies in other teaching–learning situations. Evaluation skills appraise the product or outcome and regulatory processes of the teaching–learning experience (Lucangeli, Cornoldi & Tellarini 1998).

Pedagogical content knowledge

Pedagogical Content Knowledge refers to the complex nature of a teacher's knowledge of the content (Mathematics), the learners (how they learn and understand) and teaching (available and appropriate teaching strategies and techniques). This term was coined by Lee Shulman (1987), who emphasised PCK as a subject-specific concept. Ball et al. (2008) developed a subject-specific model for school Mathematics based on Shulman's model for PCK. Ball et al. (2008) introduced the model called MKT. Mathematical Knowledge for Teaching (Ball et al. 2008) is a framework for the effective teaching–learning of Mathematics and can be illustrated as seen in Figure 7.2.

In the MKT model, Ball et al. (2008) differentiate between two interrelated domains, namely, SMK and PCK. These two domains



Source: Ball et al. (2008:403).

FIGURE 7.2: Mathematical Knowledge for Teaching.

can be distinguished but cannot be separated. Subject matter knowledge includes:

1. common content knowledge
2. knowledge at the mathematical horizon
3. specialised content knowledge.

For this research, we are not elaborating on SMK but are rather focussing on the following three elements pertaining to PCK:

1. Knowledge of the content and learners (how they learn) that binds knowledge about learners with knowledge about Mathematics (Petrou & Goulding 2011)
2. Knowledge of content and teaching that empowers the teacher to foresee difficulties and misunderstandings that learners may have and to make informed decisions regarding (available and/or appropriate) teaching–learning strategies (Petrou & Goulding 2011)
3. Knowledge of the curriculum – adherence to the CAPS curriculum as well as pace-setters to teach the topics in the allocated time frames for every grade (DoE 2011).

Pedagogies of play in Mathematics

Vygotsky (1978) believed that PoP is much needed in classrooms. According to him, play is meaningful because it creates new learning experiences in order to attain new knowledge. Neuroscientists have discovered recently that up to 400 repetitions are required by the brain to develop a synapse; however, if repetition is part of play, the number of repetitions for the synapse to develop decreases to about 10–20 (Brown 2009). (Also, refer to the insights in Ch. 4.) Teachers are hesitant to use PoP in the classroom, although learners are very receptive to such an approach (Brits, De Beer & Mabotja 2016; Remer & Tzuriel 2015), and learners have no fear of the content because learning occurs in a playful manner.

Currently, the connection between learning and play is being researched worldwide. However, there is a paucity in the literature regarding research on the use of indigenous African games as a potential (Mathematics) learning space (Nkopodi & Mosimege 2009). Using the IK embedded in games, music, art or puppetry are but a few examples of potential learning spaces in contextualising Mathematics.

Indigenous games are embedded in cultural practices and are passed down from generation to generation along with views, beliefs, values and attitudes of this specific culture (Bayeck 2018). Games engage learners on a positive level where their attitudes can be improved – they provide enjoyment, increase learners' cognitive abilities in Mathematics and play an important role in the development of their social and non-cognitive skills (e.g. patience and discipline). Worldwide, games are regarded as learning spaces to improve learning (Bayeck 2018).

According to Mosimege and Ismael (2004), the potentialities of non-Western games have not been explored sufficiently. They (Mosimege and Ismael) note that indigenous games should be considered in their entire context (historical, social and cultural), which is possible to find and use appropriately. Resources for teaching can benefit from own local and cultural resources. *Morabaraba* (Sesotho) or *Umfabafaba* (isiXhosa), as it is known in South Africa, belongs to the class of 'three-in-a-row' board games. Mosimege and Ismael (2004) identified mathematical concepts by analysing a *Morabaraba* board's various quadrilaterals, ratio and proportion between the lines, and symmetry. *Morabaraba* and *Ncuva* are well known to many South African teachers and learners, and these games support various Mathematics topics and themes (Nkopodi & Mosimege 2009).

Contextualising Mathematics

Mazzeo (2008) defines contextualised teaching as 'a diverse group of teaching strategies' to make the learning of (Mathematics) skills, content and language accessible by focussing teaching and learning on concrete applications in a specific (familiar) context. The authors argued that contextualised Mathematics could serve as a good entry point into the abstract world of Mathematics. Contextualised Mathematics provides the opportunity to give all South African learners epistemological access to good education and provides learning affordances in Mathematics (DoE 2011). Contextualising Mathematics topics in IK (games, music and puppetry) via a PoP teacher professional development SLP might result in more meaningful (Mathematics) teaching–learning and more affective engagement of learners in Mathematics learning or activities (De Beer & Kriek 2018). It is important to note that incorporating a sociocultural (contextualised) component in the curriculum acknowledges the importance of the affective dimensions in Mathematics teaching (Gavarrete 2015). When designing Mathematics lessons, mathematical ideas are deliberately embedded in IK to provide a sense of purpose and relevance for learning Mathematics in terms of the development of Western mathematical understanding (Ainley, Pratt & Hansel 2006).

Mathematising Mathematics

Mathematisation is the reverse process in which real contextual problems are expressed mathematically (abstract Westernised Mathematics semiotics), making Mathematics the vehicle for solving real problems, and it shows how Mathematics is used (Fosnot & Dolk 2001). Mathematics teachers bridge the Westernised curriculum content by contextualising and then mathematising it, making Mathematics understandable, relevant and meaningful.

Indigenous knowledge systems

There is no standard definition for IK; however, in general, it can be defined as the local knowledge that is unique to a given culture or society (Izmirli 2011). Regardless of the definition of IK, there is a consensus that various communities, cultures and societies have IK systems that evolve and change as they develop, influenced by interactions with other knowledge systems (Izmirli 2011).

When comparing IK and Western Mathematics, the first difference lies within the way they are transmitted; IK is transmitted orally, while Western Mathematics is mainly written. Secondly, IK is based on real-life observations and experiences, evaluated in the light of what one has learnt from elders or through experience, while Western science is taught and learnt often (not always) in an abstract context (Anonymous n.d.).

According to Brodie (2016a, 2016b) and the Council on Higher Education (CHE) (2017), decolonisation of the Mathematics curriculum is concerned not only with what is being taught to South African learners but also how it is taught and how teachers orientate themselves in their teaching–learning praxis. Decolonisation of the Mathematics curriculum presents an opportunity to contextualise Mathematics in IK and then mathematising it in the Western abstract way so as to give all learners access to a Westernised curriculum and enrich their overall learning and their sense of applicability of the subject (Brodie 2016a; Salami & Okeke 2017; Venkat, Bomie & Graven 2009).

As soon as Mathematics is packaged according to a specific context (contextualised through the infusion of indigenous games), the real mathematical ideas behind the topic under study are brought forth (Thornton, Statton & Mountzouris 2012). Such contextualising enables learners to mathematise their reality and understand school Mathematics based on the way the teacher contextualises the content (Fosnot & Dolk 2001). ‘Colonisation’ of the curriculum occurred when norms, practices, codes, meanings and values were ‘hidden’ from learners, leading to unawareness of the ‘ways of knowing, thinking and understandings’ that were indigenous to them and their culture (CHE 2017). This can be addressed by contextualising Mathematics topics and themes in IK.

Ethnomathematics

According to D'Ambrosio (2006), cultural contexts in Mathematics Education strongly advocate more meaningful, relevant and accessible Mathematics to learners. The incorporation of culture by means of IK practices (e.g. indigenous games) situates knowledge that already exists and can foster optimal learning experiences in the Mathematics classroom. D'Ambrosio (1984) and Mosimege (2018) explain ethnomathematics as mathematical practices by various cultural groups. This can be done using certain cultural symbols, codes, languages, values or attitudes in order for learners to access the theoretical grounding of the body of knowledge of Mathematics, whereby they identify with it, understand it and apply it. According to Fossa (2006) and Tutak, Bondy and Adams (2011), ethnomathematics refers to the different ways in which learners in cultural groups practise Mathematics and how they incorporate this authentic Mathematics, influenced by their culture and daily lives, in the reconstruction of Mathematics (mathematising) in the classroom. It can therefore be said that ethnomathematics enables learners to establish a connection between Western (abstract) mathematical semiotics, the representation thereof, as well as the imagery they establish derived from their culture, in order to understand the mathematical concept being taught.

A short learning programme in ethnomathematics as intervention

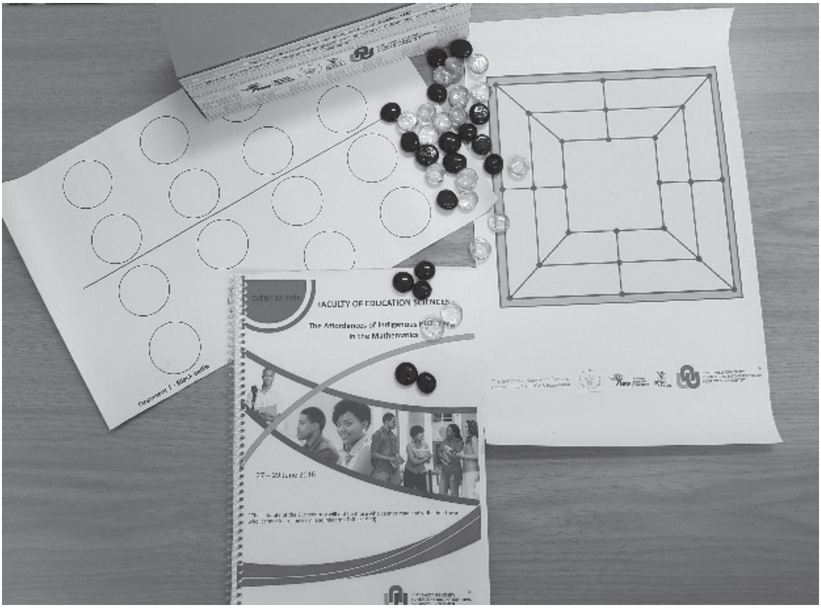
The SLP in ethnomathematics was designed to introduce Mathematics themes and topics that are contextualised in IK using a PoP. The SLP introduced teachers to various concepts and examples, including metacognition (more specifically reflection); contextualised Mathematics, using a PoP; CL – De Bono's Thinking Hats; and lesson study. Games (*Morabaraba* and *Ncuva*), music (boomwhackers) and puppetry were also used as a PoP, because it created a 'doorway' for authentic problem-solving, which relates to learners' real-life experiences (Keogh et al. 2008). The next three sections provide a brief summary of how we integrated the games, music and puppetry.

Games

Games require people to actively engage their thinking (cognition), their bodies (physically) and their feelings (about understanding Mathematics) (Corti 2006). Various researchers (Ferguson 2014; Inamdar and Kulkarni 2007; and Mustafa, Khan and Ullah 2011) found in their studies that learners in Mathematics classrooms benefitted (performance and attitude-wise) from playing interactive games. Indigenous games, such as *Morabaraba* and *Ncuva*, can be repurposed for achieving a learning goal such as the conceptual understanding of 2D geometrical figures or fractions (Naik 2015).

The game of *Morabaraba* and 2D geometrical figures

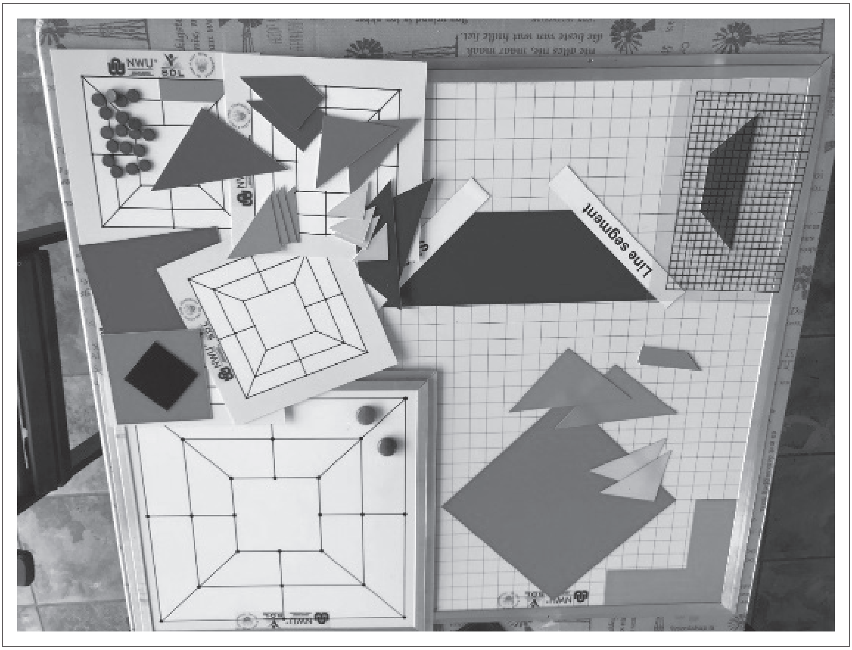
Morabaraba (Figure 7.3) involves two players and involves strategic thinking. When the game commences, each player has 12 'cows' (tokens) that are placed strategically and alternatively on a *Morabaraba* board at intersections of straight lines. The aim is to put three tokens in a row: vertically, horizontally and diagonally on open intersections. When a player gets three tokens in a row, he or she may remove a token of the opponent, not breaking a three-in-a-row placement of the opponent. The removed tokens may not be placed back on the board again. When all tokens are placed on the board, the second phase



Source: Photograph taken by Erika Potgieter, exact date and location unknown, published with permission from Erika Potgieter.

FIGURE 7.3: Initial *Morabaraba* and *Ncuva* games provided during SLPs.

commences where players can move a token to an open adjacent intersection. During the third phase, the last level commences when at least one of the players has only three tokens left. These three tokens may 'fly' to any intersection on the board with each turn of the player. There are more rules for more advanced players available on the website (as listed above the list of references). The game is over when one player has only two tokens left on the board or when one player cannot move any of his or her tokens. The game ends in a draw when one player has three tokens but is unable to remove one of the opponent's tokens within 10 moves. The winner is the opponent who could remove all but two tokens of the opponent.



Source: Photograph taken by Marthie van der Walt, exact date and location unknown, published with permission from Marthie van der Walt.

FIGURE 7.4: *Morabaraba* game board with puzzles, tokens as part of the Tshimologo Mathematics Shoestring Kit.

In this research, puzzles of 2D geometric figures available on the game board were cut to introduce the different figures and to build other figures with two or more puzzle pieces, grid paper to allow for teaching perimeter and area with puzzle pieces, as well as appropriate mathematics vocabulary.

The game of *Ncuva* and case-based teaching

Ncuva (also known as *Moruba*) is a strategic board game involving problem-solving skills. The aim of the game is to play until one's opponent has lost all of his or her 'cows' (pebbles). The 'cows' are small pebbles, pips or seeds that are used as tokens in the game.

Small holes are dug in the ground or the game can be played on an official board or a piece of paper (using circles, not holes). Two 'cows' are placed in each hole. The aim of the game is to capture as many of the opponent's 'cows' as possible. This two-player game is separated by a 'river' (line), which is the boundary for each, as illustrated in Figure 7.5.

In this research, *Ncuva* was incorporated during the SLP. The game was infused with fraction concepts and presented to teachers, using a case-based teaching strategy.

Case-based teaching is a pedagogy that emphasises learning from practice. Merseth (1996:724) describes cases as narratives that are infused with dilemmas that can be analysed from various perspectives. It can assist learners to explore 'the messy problems of practice'. It is an attempt to bridge the so-called theory–practice divide by providing authentic teaching–learning experiences and assessment opportunities for teachers' PCK. A worksheet with examples was included in the SLP study guide. The case was based on an inexperienced, in-service teacher who incorporated *Ncuva* into a Mathematics lesson to introduce common fractions. The questions the authors defined in the case of *Ncuva* highlighted how participating teachers could incorporate an indigenous game like *Ncuva*, repurposed to teach fractions in order for learners to come to a conceptual and procedural understanding thereof. According to Gallucci (2008), case-based teaching allows for a critical reflection on participant teachers'

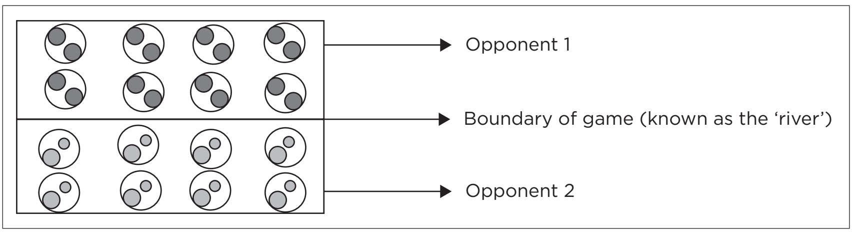


FIGURE 7.5: *Ncuva* game board.

Source: Photograph taken by Josef de Beer, exact date and location unknown, published with permission from Josef de Beer.

FIGURE 7.6: *Ncuva* game board at a cultural village in North-West province.

own teaching–learning praxis. The use of cases in teacher professional development is based on the assumption that teachers, via discussion of and reflection on cases (authentic teaching–learning experiences), reflect on how educational theory can inform practice, and when these teachers enter their classrooms, they will be better prepared for the realities of the classroom and will critically analyse their own practices to improve learners' learning by applying sound theories to classroom situations (Malkani & Allen 2005).

Music and boomwhackers

Everybody knows both music and Mathematics, which form part of our everyday lives. Although music and Mathematics seem to

Source: Photograph taken by Josef de Beer, exact date and location unknown, published with permission from Josef de Beer

FIGURE 7.7: Participants exploring boomwhackers and Mathematics concepts.

have no apparent connection, they share a valuable link. Few people have the privilege to study music and its theory, while Mathematics or Mathematics literacy is a compulsory school subject from Grade R–12. As was previously mentioned, when Mathematics is presented in a rational, Westernised abstract manner, some learners feel anxious, have no interest in Mathematics and sometimes experience Mathematics as meaningless. Music, on the other hand, relates to feelings and emotions in people's everyday lives, and people love listening to, making and playing music (Glydon n.d).

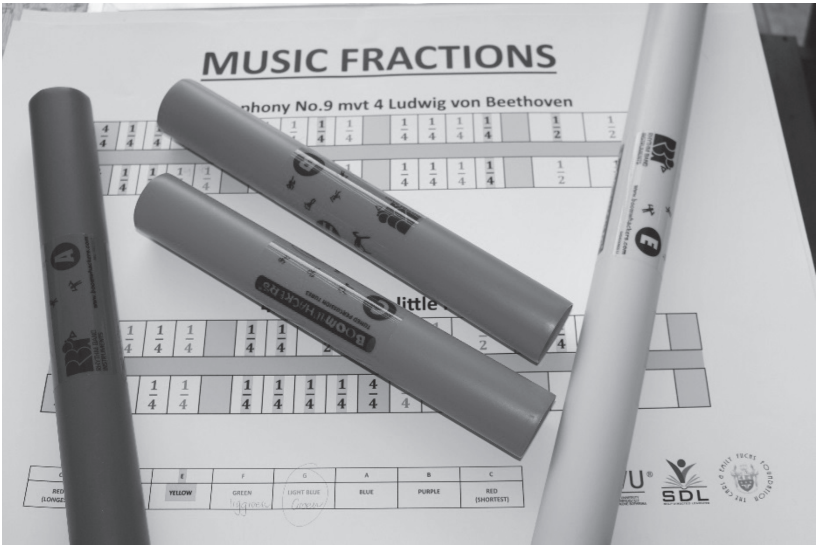
In this research, we used music and boomwhackers to introduce and practice the common fraction concept.

Boomwhackers (Figure 7.8 and Figure 7.9) are coloured plastic tubes, accurately cut into specific lengths to produce different tones when hit against a surface (table, hand or floor) and work like xylophones. Music symbols (notes such as ♪) of a few songs were transposed to mathematical symbols (fraction format, e.g., $\frac{1}{4}$; $\frac{1}{2}$). The fractions on the posters we used were colour-coded to correspond with the tone and the specific colour of the corresponding boomwhacker. The size of the fraction indicated the time duration of the hit.

Learners' Mathematics performance and attitudes improve as a result of teaching Mathematics and music in an integrative way (An & Capraro 2011). When Mathematics is contextualised, both cognitive and affective experiences are included (Selwyn 1993), which impact positively on their performance in Mathematics.

Source: Photograph taken by Erika Potgieter, exact date and location unknown, published with permission from Erika Potgieter.

FIGURE 7.8: Boomwhackers – Part of the Tshimologo Mathematics Kit.



Source: Photograph taken by Marthie van der Walt, exact date and location unknown, published with permission from Marthie van der Walt.

FIGURE 7.9: Boomwhackers and sheet music as used in this research.

■ Puppetry

The puppets used in this research portray various cultures across South Africa. Animal characters are also used, as animals have a rich history in especially some of the cultures. Storytelling is deeply rooted in various South African cultures, and puppetry becomes a 'vehicle' where new knowledge is 'discussed' and 'performed' in a playful manner. In this research, we adapted indigenous tales from San and Sotho people (using the characters in Figure 7.10) and adapted them to a dialogue format. The stories were contextualised and mathematised with certain principles.

The teachers had to act out the dialogue to colleagues, and questions were asked afterwards as to which Mathematics principles could be integrated into such a tale. One tale was

Source: Photo taken by Erika Potgieter, exact date and location unknown, published with permission from Erika Potgieter.

FIGURE 7.10: Puppet characters used in this research.

about Little Hare Harelip (a San tale), which dealt with why a rabbit had a split lip. In the story, the hare had to travel quite a distance in order to deliver a message to 'the men of the veld'. For Intermediate Phase learners, the Mathematics principles of measurement (pertaining to length) were infused into this story – questions regarding the distance travelled by the hare could be posed to these learners. For Senior Phase learners, analytical geometry principles apply where the distance between two points (one character and another in the story) could have been used in order for learners to calculate and perform this operation and understand and remember the concept thereof.

The teachers were provided the opportunity to engage in developing activities, using the idea of contextualising Mathematics in IKS and developing skills (such as PoP and CL) to implement these approaches in their own classrooms. The teachers also received some of the resources to use in their classrooms.

Ethnomathematics was used as the point of departure in the SLPs presented across two provinces in South Africa. The professional development of teachers during these SLPs was aimed at creating awareness as to how learners' real-life experiences and their IK can contribute to the applications of Mathematics, allowing for decolonisation to occur (Venkat et al. 2009). During the SLP, the integration of PoP allowed the participant teachers to not only decolonise the Mathematics content but also engage in problem-solving and critical thinking, while being professionally developed to incorporate various learner identities into the teaching–learning content of school Mathematics (Brodie 2016b).

In this research, we based our SLP's professional development principles on the ZPTD, as suggested by Warford (2011). This author applied the well-known Vygotskyan (1978) construct of the ZPD to a teacher education context. In teacher professional development interventions, teachers are not always provided the opportunity to practise what they have learnt (Myende 2014). The SLP afforded the teachers the opportunity to gain new knowledge, practice and, by means of a portfolio, provide evidence of the application of their newly gained knowledge in their own classrooms. In this research, the ZPTD was applied as seen in Table 7.1.

■ Empirical design of the study

The empirical design of the study took the form of a multi-method qualitative approach with elements of phenomenology considered through an interpretivist paradigm. We wanted to establish the participants' lived experiences during the SLP and after the SLP when they had to contextualise their lessons in IK (games, music and puppetry) based on a PoP. The focus of this study is participants' lived experiences of the affordances of contextualising Mathematics IKS (games, music and puppetry) using PoP during and after a teacher professional development intervention in ethnomathematics,

TABLE 7.1: Stages infused into our SLPs cycles based on the ZPTD.

Stage in ZPTD	Description of stage	Activities during the SLPs
Self-assistance stage	Reflecting on own teaching–learning praxis, recalling prior experiences, needs or problems faced in the Mathematics classroom	Pre-questionnaires were given to teachers where they reflected on their experiences in the Mathematics classroom, including their knowledge and experience of contextualised Mathematics.
Expert-other stage	The scaffolding of knowledge based on the assistance of a knowledgeable other	Teachers engaged in case-based teaching, PBL, as well as CL techniques like De Bono's Hats, puppetry and the playing of music with boomwhackers.
Internalisation stage	Reflection on professional development intervention where attained knowledge and concepts are reviewed and discussed	Teachers had to reflect on the professional development intervention by answering prerequisite questions contained in the SLP study guide. These reflections had to be submitted together with their lesson plans as part of their portfolios.
Recursion stage	Theory is put into practice and participants are afforded the opportunity to put to effect what they have learnt during the professional development intervention	The portfolios had to be submitted based on contextualised Mathematics lesson plans. Teachers could have used the adapted versions of the example contextualised Mathematics lessons presented at the SLP or they could have developed new lessons for their classrooms. The portfolios served as evidence of how they transferred theory to practice and had to be submitted 5 months after the SLP.

Source: Warford (2011:254).
SLP, short learning programme; ZPTD, Zone of Proximal Teacher Development.
The design of the SLP allowed the researchers to collect the data as captured in the empirical design of the study.

contributing to their reflective praxis (metacognition) (Creswell 2014).

Pedagogies of play infused with IK might hold affordances that other pedagogies (such as transmission-mode teaching) might not present and may assist teachers in teaching–learning to improve access to concepts, procedures and relationships in abstract school Mathematics, making it more meaningful and accessible to learners when contextualised (Brits et al. 2016; Rusling 2009).

Sampling

The study took place in two South African provinces. Overall, purposive and convenient sampling schemes were applied. In line with the SLP intervention, these sampling schemes catered for minimal logistical issues (Collins, Onwuegbuzie & Jiao 2007). Table 7.2 offers an overview of the number of samples we used per data format collected.

Data collection instruments

The instruments employed for data collection included open-ended questionnaires, focus group interviews and evidence-based portfolios. Furthermore, content analysis was based on the conceptual–theoretical framework of the study. Participants engaged in portfolio activities, which included metacognitive activities in (ethno)mathematics lessons and classroom activities.

The participants reflected on and engaged in a series of tasks (submitted as an evidence-based portfolio) to develop their own contextualised Mathematics activities or lessons or to use the examples presented at the SLP to plan, adapt and teach lessons in their own classrooms. A multi-method data collection plan was implemented. The focus of all the data collection instruments was on teachers' perceptions of using IK in Mathematics classes and real experiences about their Mathematics lessons

TABLE 7.2: Samples per format of the collected data.

Format of the data	Population attending the SLPs		Actual submitted portfolios and questionnaires by participants	
	Limpopo	Northern Cape	Limpopo	Northern Cape
Open-ended questionnaires	69	40	29	23
Focus group interview	12	0	0	0
Evidence-based portfolios	69	40	19	10

SLP, short learning programme.

(they planned and taught) that were contextualised in IK (games, music or puppetry). The following data collection instruments apply.

Open-ended questionnaires

In this research, participants completed an open-ended questionnaire based on their views on IK, largely adapted from the Views on Indigenous Knowledge (VNOIK) instrument by Cronje, De Beer and Ankiewicz (2015).

Focus group interview

Participants were invited to participate in a focus group interview in Limpopo. Twelve teachers participated in the focus group interview. The focus of this interview was on contextualising Mathematics in IK (in general) and the *Ncuva* case.

Evidence-based portfolios

The SLP was an accredited teacher professional development intervention. Participants were not obligated to submit portfolios. They could choose whether they wanted to earn professional development points from the Department of Basic Education (DBE) or whether they wanted to obtain a certificate for the successful completion of the SLP in ethnomathematics by submitting an evidence-based portfolio.

Content analysis

In this study, we applied content analysis in line with the conceptual–theoretical framework to explore the experiences that arose from an SLP in teacher professional development. Data were obtained from a variety of methods, including open-ended questionnaires, a focus group interview and evidence-based portfolios.

TABLE 7.3: Main themes and sub-themes identified in this study.

Theme number	Main themes	Sub-themes
1	Teachers are of the opinion that their PCK and metacognitive skills improved.	1. Teachers expressed appreciation of PoP (games, music and puppetry) as a means to contextualise Mathematics, contributing to their overall PCK. 2. Teachers' views on contextualising Mathematics in IK in Mathematics lessons became more nuanced and changed their views on their overall teaching–learning. 3. Teachers realised the need for collaborative lesson study where they could learn with and from one another. 4. Teachers took responsibility for their own learning, thus reports on enhanced SDL. 5. Teachers commented on affective outcomes of the SLP, and expressed increased levels of motivation. 6. Teachers mentioned that they still feel underprepared to integrate IK in Mathematics lessons. 7. Teachers are unprepared or underprepared for contextualising Mathematics in IK.
2	Teachers reported on enhanced learning in the classroom and the realisation of affective outcomes.	1. Teachers commented on the affective affordances of PoP for learners and their learning. 2. Teachers spoke about enhanced understanding of Mathematics concepts using a PoP. 3. Teachers mentioned that learners are motivated and engaged in the new learning environment. 4. Teachers commented on how such PoP could address cultural diversity in the classroom.
3	Systemic factors such as the school environment, parents and language may impede the transfer of knowledge and skills.	1. Teachers are of the opinion that parents cannot support their children with IK assignments. 2. The teachers mentioned the CAPS, time management and a lack of resources as challenges in their schools. 3. Teachers mentioned that overcrowded classes and lack of discipline negatively influenced their daily teaching. 4. Teachers mentioned that language barriers are a challenge in multi-lingual classrooms.

PoP, pedagogy of play; PCK, pedagogical content knowledge; CAPS, Curriculum Assessment Policy Statement; IK, indigenous knowledge; SLP, short learning programme.

Triangulation

In addition to applying content analysis, we adopted triangulation as a method for synthesising the findings obtained from this generic qualitative study (with elements of phenomenology) to represent the findings. In addition, as triangulation caters to the validation of data through the representation of the multiple methods used, various aspects of the same phenomenon can be presented. Through such cross verification, we corroborated the analysis of content from the data collected and aimed to satisfy the readership regarding the validation of the study. Validation and trustworthiness measures included triangulation of the data obtained, inter-coder reliability among the authors and following a multi-method approach. Through inter-coder reliability, we signify the degree to which different coders assigned the same themes to the data content. The authors collaborated on the consistency of the themes and followed the guidelines by Elliott, Fischer and Rennie (1999). These guidelines include associating the findings with the conceptual–theoretical framework of the study and providing an in-depth description of the empirical investigation. We also employed within-method triangulation where open-ended questionnaires, the focus group interview and evidence-based portfolios served as different methods within a qualitative approach (Curtin & Fossey 2007).

Presentation of the findings

To present our findings, we have identified the following three main themes via *a priori* coding, which emerged from the open-ended questionnaires, the focus group interview and evidence-based portfolios, fostering the affordances of IK for Mathematics Education.

Teachers and teaching: Teachers are of the opinion that their pedagogical content knowledge and metacognitive skills improved

Participants reflected critically on their own teaching–learning praxis. The following sub-themes emerged, and we provide data that underpin the sub-themes.

Firstly, the appreciation of PoP (games, music and puppetry) to contextualise Mathematics, contributing to their overall PCK:

> Learners like to play all the time. When I invited them to play, they were very excited and I could see they understood the lesson. (P11, undisclosed gender, date unknown)
>
> Learners learn easy through play. The transition from playing *Morabaraba* into classifying geometry concepts from the board game, will be better facilitated through the development and use of a worksheet. (P10, undisclosed gender, date unknown)
>
> There is room for play in Mathematics. Mathematics doesn't need to be rigid [...] We can play, be noisy and work with or play against or differ from peers. We should learn to communicate differences and resolve problems collaboratively. (C10, undisclosed gender, date unknown)
>
> Initially I was stressed using puppets, but when I saw how much the learners were enjoying and focussing on the puppets, I relaxed. In the end, I enjoyed it as much as the learners did. I think because learners are enjoying puppets, their learning accelerates [...] games are good for concentration [...] The class was noisy [...] Learners who used to be passive were [...] discussing symmetry and planning solutions. There was no time to talk other stuff, but they have enjoyed it. (C4, undisclosed gender, date unknown)

Secondly, teachers' views on contextualising Mathematics in IK in Mathematics lessons became more nuanced and changed their views on their overall teaching–learning:

> Learners were quick to show me two games they play in the Calvinia area. These games require you to jump from one figure

> to the next one. You have to draw different figures in the sand. The one is called Michael Jackson Hockey and the other one Ten Hare. (C9, undisclosed gender, date unknown)
>
> I am “hooked” on the use of indigenous games [...] and my learners are too. I start everyday with indigenous games. (C9, undisclosed gender, date unknown)
>
> Success rates implementing indigenous games are high. It changes learners’ attitude towards the subject. I see their enthusiasm and participation [...] when there is time on hands, they play the games. (C9, undisclosed gender, date unknown)
>
> I designed a game based on sheep farming because most of the learners live on or their parents work on sheep farms in the area. Learners are allowed to play the game toward the end of the lesson. Playing games is fun and learners don’t think they are learning. In this game learners compete against one another. (C10, undisclosed gender, date unknown)

Thirdly, teachers realised the need for collaborative lesson study where they could learn with and from one another:

> I got the opportunity to meet up with other educators and we shared our frustrations and came up with ways of how to solve them. (P1, undisclosed gender, date unknown)
>
> In the future when presenting lessons [...], I will consult with educators who are more knowledgeable. (P16, undisclosed gender, date unknown)
>
> I will adjust my mind-set by creating support groups with colleagues and reading more books and journals. (P15, undisclosed gender, date unknown)
>
> There is a need for teachers to work together on problem-solving before teaching it to learners. (P21, undisclosed gender, date unknown)
>
> Colleagues can discuss (a PoP) during subject meetings. The ‘trick’ will be to plan something (a working document) to present at the meeting that will be interesting to them. (C10, undisclosed gender, date unknown)

> I would like to share my experiences with my colleagues and encourage them to also implement (the indigenous games). (C4, undisclosed gender, date unknown)

Fourthly, teachers took responsibility for their own learning:

> I will do research on indigenous knowledge and talk to older people in the community so that I can get better ways to reach the learners and make Mathematics fun for them. (C6, undisclosed gender, date unknown)
>
> I realised that one is never too old to learn. I thought the way I was teaching was perfect, but I saw that the new approach worked well. I realised that I don't have sufficient indigenous knowledge that can simplify our lives. (C7, undisclosed gender, date unknown)
>
> I realised that one can't put everything you do in a box and later take it out to work with it again. You, as the teacher should be innovative yourself: think about strategies, plan lessons and monitor your learners. You can get solutions to the challenges in your situation. (C9, undisclosed gender, date unknown)

Fifthly, teachers commented on affective outcomes of the SLP:

> I got a lump in my throat, when I saw how much the learners were enjoying the lesson. I could also observe that the learners were not arguing … and no disciplinary challenges occurred. (C7, undisclosed gender, date unknown)
>
> I feel good about everything. I like learning new things and I have learnt about myself as well. You have made me think about teaching in different ways. (C4, undisclosed gender, date unknown)
>
> When learners were playing *Morabaraba* and the other games, I have felt closest to my learners. They had been so excited and positive that I felt I could change the world with them. (C9, undisclosed gender, date unknown)
>
> Both the learners and I had a positive experience of the lesson. Learners were very excited because they understood the work. I think it's because I have included real-life examples. The learners participated in the discussion. (C10, undisclosed gender, date unknown)

Sixthly, teachers realised how their teaching benefitted from their own reflection:

> As the teacher, I have to reflect on a daily basis on what worked and what didn't work. What didn't work, you have to change it to make it easier for the learners… Reflection taught me to look critically at myself, change isn't easy but necessary. I will definitely use puppetry again in my maths classroom. (C4, undisclosed gender, date unknown)

Teachers were able to reflect critically on their own teaching–learning praxis and on a PoP that created an environment in which games, music and puppetry could be 'experimented' with, resulting in some successful experiences. Mathematics teachers are appropriately placed with their mathematical knowledge to translate the learners' knowledge into meaningful mathematical explorations.

However, certain challenges regarding participant teachers' teaching–learning also emerged from the data.

Seventhly, teachers mentioned that they were underprepared to integrate IK in Mathematics lessons:

> At times, it was difficult to control learners because learners in this Mathematics classroom have not been exposed to playing board games before during the Mathematics period. (P10, undisclosed gender, date unknown)

> I didn't know that incorporating IK can assist the learners to understand mathematical concepts so easy. I am a teacher who is eager to learn all the time. The curriculum is changing all the time and new approaches to mathematical problems are ever changing to suit the current situation on which I need to be on par with. (P4, undisclosed gender, date unknown)

> Planning this lesson was a bit frustrating and finding the link to incorporate IK was difficult. (P3, undisclosed gender, date unknown)

> Enough resources to use will help overcome overall difficulty in implementation of IK. (P8, undisclosed gender, date unknown)

Although these challenges were mentioned by participants, there is a need for frequent follow-up workshops to ensure sustainability of teachers' efforts to contextualise Mathematics in IK using a PoP.

The findings in this research support the findings of research conducted by Avalos (2011), concerning the collaboration between teacher participants at professional development interventions, where they tend to share ideas and experiences, becoming more aware of problems (and conceptualising solutions) faced in the teaching–learning of Mathematics. Teachers need to experiment with and reflect on what they attain during the intervention and compare it with their own professional environments (Girvan, Conneely & Tangney 2016).

Learners and learning: Teachers reported on enhanced learning in the classroom and the realisation of affective outcomes

Participants reflected on learners' learning. The following sub-themes emerged.

Firstly, teachers commented on the affective affordances of PoP for learners and their learning:

Learners enjoyed the activities a lot. They were all eager to play. (P11, undisclosed gender, date unknown)

Learners were all excited and volunteered to take turns in their participation of the games, music and puppetry. Even the weaker learners had the opportunity of contributing during the lesson. (P3, undisclosed gender, date unknown)

I started to get learners' attention while unpacking the new game (*Morabaraba*) and explaining to them that we are going to use the game in the Mathematics lesson. They were very curious about the game, because they didn't know the game. I explained the game rules and was surprised that they understood the rules and mastered the game in no time. I continuously prompted them about 2D figures. (C7, undisclosed gender, date unknown)

The learners enjoyed identifying the figures and going out to find the figures in nature and afterwards painting the figures on stones. They were amazed to find the 2D-figures in nature. Their self-confidence grew and they mentioned that they felt an appreciation for nature. (C3, undisclosed gender, date unknown)

The enthusiasm of the learners amazed me: they mastered the game; they played collaboratively, they understood the concepts of 2D geometry figures – even the weaker learners did [*understand and play*]. (Unknown participant, undisclosed gender, date unknown)

Secondly, teachers spoke about enhanced learner understanding of Mathematics concepts using a PoP:

> The assessment of learners' worksheets showed that they were able to discover and learn the concept of fractions embedded within the *Ncuva* board game. (P10, undisclosed gender, date unknown)
>
> The *Morabaraba* game had a holistic approach regarding the teaching of geometry – learners were able to relate easily to the different concepts involved. (P12, undisclosed gender, date unknown)
>
> What learners learn is determined by how they learn. (C10, undisclosed gender, date unknown)
>
> I realised again the learning in groups is important in the classroom. Learners learn from one another because they use the same language. (C3, undisclosed gender, date unknown)
>
> If we learn in a playful manner, it will create a nice atmosphere in my class and learners will more freely participate in activities [...] and learners are happier and they will understand the work better. (C4, undisclosed gender, date unknown)

Thirdly, teachers mentioned that learners are motivated and engaged in the new learning environment:

> The integration of IK resulted in a classroom where learners were able to share their views and justify their thinking processes. (P10, undisclosed gender, date unknown)

> My learners enjoyed my class so much, that they do not want to miss another class. (P13, undisclosed gender, date unknown)

> I realised that my learners grasped the subject matter more easily when using indigenous games rather than ordinary scenarios. They were actively involved and motivated to learn. (P16, undisclosed gender, date unknown)

> Indigenous games motivated the learners and they enjoyed working together. (P10, undisclosed gender, date unknown)

Fourthly, teachers commented on how such PoP could address cultural diversity:

> It provided the opportunity for interaction among the different learners in my classroom. (P19, undisclosed gender, date unknown)

> The incorporation of IK in my classroom will lead to learners, becoming adults who appreciate other cultures and other- and own value. (P3, undisclosed gender, date unknown)

> They (the learners) understand more than ever before that different cultures can learn from one another and that we are inseparable in learning and living. All have interesting and important materials we have to use to make a success for all. (C9, undisclosed gender, date unknown)

The overall response when infusing lessons with IK (via games, music and puppetry) were well received among learners, and participants could see a difference in their learning. A challenge that emerged under this theme, according to the participants, is:

- These challenges are difficult in a multi-racial, young South Africa, but IK provides an all-inclusive learning space where learners not only learn from one another but also stay engaged (maybe across multi-grade or overcrowded classrooms). (Unknown participant, undisclosed gender, date unknown)

While transfer of knowledge, skills and characteristics is the ultimate goal of all education, learners are expected to internalise what they learn in school and apply it to real life. Educational success is no longer mainly about reproducing content knowledge but about transferring what we know and being able to apply that knowledge, skills and character in new contexts or situations. These changes require different pedagogies in teaching Mathematics (Fadel, Bialik & Trilling 2015).

Systemic factors such as the school environment, parents and language may impede the transfer of indigenous knowledge and skills

Another sub-theme that emerged from participants' responses was the influence of the school environment and parents.

Teachers are of the opinion that parents cannot support their children with IK assignments:

> Parents are illiterate and cannot assist learners at home with homework [...] Indigenous games are on the learners' level, they can bring things from home and still be able to learn. (P6, undisclosed gender, date unknown)
>
> The school is located in a very poor district and the parents are dependent on grants, influencing the discipline at the school and leading to overcrowded classes. (P18, undisclosed gender, date unknown)
>
> Parents in the community are not interested in the school or their children – they show no interest and accountability towards their children. They don't attend parent-evenings. (C10, undisclosed gender, date unknown)

The use of IK in the form of games, music and puppetry allowed for an overall positive school environment. From the participants' responses, the following barriers surfaced in this theme.

The teachers mentioned the CAPS, time management and a lack of resources as challenges in their schools, in using PoP:

> I would like to improve my time management when giving lessons like these. (P14, undisclosed gender, date unknown)

> IK is an interesting concept to integrate, although the availability of resources, effective time management and a lot of topics to be covered in the CAPS plays a role. (P9, undisclosed gender, date unknown)
>
> The overloaded curriculum and the time schedule provided by the Department of Basic Education challenges both teachers and learners. (C10, undisclosed gender, date unknown)
>
> A lack of finances to buy calculators for learners at schools who serves a poor community, teachers [...] get demotivated [...]. (C10, undisclosed gender, date unknown)

Teachers mentioned that overcrowded classes and lack of discipline negatively influenced their daily teaching:

> I will have to improve on time management when teaching IK, since I teach in very overcrowded classrooms in a township. (P6, undisclosed gender, date unknown)
>
> At times, it was difficult to control learners because learners in this Mathematics classroom have not been exposed to playing board games before during the Mathematics period. (P10, undisclosed gender, date unknown)
>
> Discipline is an enormous problem at my school – every day you have to struggle through the chaos of no discipline. There is no culture of learning in my school. (C7, undisclosed gender, date unknown)

Teachers mentioned that language barriers are a challenge in multi-lingual classrooms:

> The most difficult part of teaching the lesson was letting learners construct their own rules or patterns. This was because of the language barrier. Learners need to have more Mathematics vocabulary to help them construct their own questions and most importantly, think constructively about Mathematics. (P1, undisclosed gender, date unknown)

These were the most common challenges experienced among the participants, but overall, the affordances of contextualising Mathematics topics or themes in IK (in the form of games, music and puppetry) seem to have overcome the reality of the school environment and the surrounding community. These approaches were cost-effective because learners were able to bring waste materials from home to enrich and engage the teaching–learning experience together with their Mathematics teachers.

Conclusion

In order to teach 21st century learners, a 21st-century teaching–learning approach is necessary where learners' expertise, imaginations, playfulness and improvisational competence comes to the fore – all of which is present when a PoP is used in the classroom (Miyazaki 2010).

Brown (2008) states that learning is contextualised owing to the influences of the environment. The participants were able to reflect on their own teaching–learning praxis. They acknowledged the affordances of contextualising Mathematics topics or themes in IK (in the form of games, music and puppetry) and also suggested strategies for self-improvement and collaboration between themselves and their colleagues in the future. The impact of IK on the learning environment was overall positive as teachers in the interviews and evidence-based portfolios highlighted that learners displayed enjoyment, participation, enhanced understanding and curiosity. The systemic factors such as the school environment, albeit challenging (socio-economically), provided a context for learning, which was also a positive attribute, as it enhanced social skills and collaboration despite being pressurised by a content-laden curriculum and few resources.

This research was conducted in the context of teachers in two provinces in South Africa. The data illustrate the need for such continuing professional development SLPs – using metacognition as reflective methodology. However, based on our experiences in these two provinces, and based on design principles that were distilled, the SLP should be redesigned for other provinces, taking local context into consideration. An aspect to consider in future SLPs is CAR, where teachers engage in joint teaching and CAR with peers, in attempts to contextualise (decolonise) Mathematics topics and mathematise it. Gravett and De Beer (2015) show that CAR can assist teachers in becoming more critical reflective practitioners. If teachers continue to implement and practise this enhanced PCK they have obtained, they would master the content provided during the intervention (Osborne et al. 2013). The most important aspect is that teachers would transfer what they have learnt to their classrooms and schools. According to Girvan et al. (2016), teachers need to experiment with and reflect on what they attain during SLPs and while in their own professional environments. According to Myende (2014), teachers' views, ideas and expertise should be included in the design phases of contextualising Mathematics topics in IK.

Future research should focus on the implementation and integration of the Tshimologo Mathematics Shoestring Kit (funded by the Fuchs Foundation) in the Mathematics classroom, which was developed during the course of this research by one of the authors (Van der Walt).

Summary

To use Mathematics effectively is part of our lives and the 21st century world of work. The need for content relevance and contextualised work embedded in Mathematics learning could enable teachers to share their teaching experiences with others and, in doing so, help develop contextualised lessons, reflect on practices and implement new pedagogies. Contextualised Mathematics aims at making Mathematics more accessible and meaningful to all learners. There is, however, a need for research invested in Mathematics teachers' PCK in their own local and IK contexts, and their own readiness to contextualise and mathematise it. This chapter presents the research conducted on a developed SLP – as an intervention for professional teacher development – at one university, implemented across two provinces in 2016–2017. Participating teachers had the opportunity to play *Ncuva* and *Morabaraba* to see how Mathematics can be contextualised in these two games. *Ncuva* was used to help learners with the concept of common fractions, and figures were cut off a *Morabaraba* board to introduce 2D-geometry concepts from a familiar situation. We used magnetic mathematical vocabulary strips as well as grid paper. Teachers were also presented with posters with music tunes transposed as common fractions and colour-coded to correspond with the boomwhacker of the same colour. In this chapter, we have presented the findings on the affordances of contextualising Mathematics topics in IK contexts (e.g. games, music, and puppetry). Data were obtained from the participating teachers by means of open-ended questionnaires, a focus group interview and evidence-based portfolios (consisting of lesson plans and reflections). Content analysis was used to establish three main themes, dealing with teachers and teaching, learners and learning, and school environment and parents. Participants had an overall positive experience of attending the SLP as well as of transferring the knowledge gained during the SLP to their own classrooms. However, various challenges arose based on their limited PCK and IK; they were never prepared for or introduced to planning and teaching contextualised Mathematics topics. Challenges such as the content-laden CAPS curriculum and a tight work schedule (pace-setters) for the completion of topics, limited the implementation of what had been learnt at the SLP or prevented them from compiling and submitting the evidence-based portfolio. It seems as if some of the participants who did submit portfolios were unfamiliar with reflective practice. The first affordance of contextualising Mathematics in IK was the participants' positive responses to the opportunity they had to improve their own PCK and that they were introduced to Mathematics contextualised in IK. It was confirmed that participants were provided a space where they could talk, listen, learn, design lessons, present lessons, discuss and reflect during the SLP and in their portfolios. The reflection done in the portfolios, open-ended questionnaires and a focus group interview enabled them to look at themselves through a lens of self-improvement based on their teaching–learning actions, transferring the SLP skills and knowledge to their own classrooms for effective, accessible and meaningful teaching–learning experiences in some Mathematics topics. The second affordance theme that emerged was about participants' experiences of their learners enjoying (affective aspect of learning) the contextualised Mathematics lessons and understanding (learning) Mathematics. The last affordance theme focussed on challenges most schools experience, such as lack of funding, lack of discipline or lack of parental support and overcrowded classrooms – all factors that might influence such contextualised Mathematics teaching and learning.

Acknowledgements

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Videos of the SLP can be viewed at:
- https://www.youtube.com/watch?v=hrA3_MpsA2Q&t=257s
- https://www.youtube.com/watch?v=7d3Zt-ZsGA4

Rules of the indigenous games can be downloaded from:
- Department Sport and Recreation. 2017. Indigenous games general and code specific rules. https://www.srsa.gov.za/sites/default/files/2017%20-%20IG%20GENERAL%20AND%20CODE%20SPECIFIC%20RULES.pdf

Chapter 8

Engaging in indigenous technology: Conceptualisation and contextualisation in problem-based environments

Marietjie Havenga[a,b]
[a]School of Mathematics, Science and Technology Education, Faculty of Education, North-West University, Potchefstroom, South Africa
[b]Research Unit Self-Directed Learning, Faculty of Education, North-West University, Potchefstroom, South Africa

Introduction

According to UNESCO (2017):

> [*L*]ocal and indigenous knowledge refers to the understandings, skills and philosophies developed by societies with long histories of interaction with their natural surroundings. For rural and indigenous

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> people, local knowledge informs decision-making about fundamental aspects of day-to-day life. (n.p.)

Gandile, Tessema and Nake (2017:168, 169) stipulate that IK encapsulates among others local knowledge, traditional knowledge, health knowledge, ecological knowledge and indigenous technical knowledge. They argue that 'IK develops in local contexts to solve local problems', for example, the maintaining of human livelihood (Gandile et al. 2017:167, 169). From an epistemological point of view, IK is based on inherited knowledge and associations. Indigenous knowledge is used by individuals who relate to distinctive indigenous environments and cultural assets, which comprise values, beliefs and practices as developed over time and as communicated across generations (Gumbo 2015; Jones, Buntting & De Vries 2013; Lanzano 2013). Indigenous knowledge involves inherited experiences of observation, instinct and the sharing of ideas (Shubeena et al. 2018). Consequently, it is owned in a particular cultural setting and elaborates on the situated knowledge of parents, family, the elders and ancestors in a community. The conjecture of IK may involve mechanisms analogue to object-oriented programming, which is a paradigm that incorporates inheritance for the purpose of reuse and extension (Sebesta 2008). A subclass inherits all the functionality from the superclass and may add additional functionality. Reuse of code through inheritance involves that programmers can use a class higher up in the hierarchy that is already created without writing it again. Likewise, where inheritance is a matter of principle in IK, the author applies the following mechanisms in the context of IK:

- *Encapsulation*: The protection of knowledge and behaviour within a particular community
- *Reuse*: The use of IK in well-known contexts as communicated across generations
- *Extension*: The elaboration of IK to address local problems
- *Polymorphism* (= many forms): The application of IK in different ways and new contexts to solve local problems.

Thus, implementation of IK requires particular knowledge, skills and behaviours, and these should be preserved for the future.

Incorporating IK into education is crucial to enable learners in valuing the history of their natural environment and nourishing it across generations. In their policy documents, the DBE focuses on 'valuing indigenous knowledge systems' as a treasured resource of history and heritage (DBE 2011:4). To adhere to the principles of the policy documents, it is expected of teachers to integrate their subjects with IK. Nevertheless, teachers, especially technology teachers, are not necessarily familiar with IK in their subject discipline. Moreover, if one looks at the research literature, it seems as if IK is mainly implemented in Mathematics, Life Sciences and Natural Sciences curricula (Mentz & De Beer 2017). Integrating IK in the technology curriculum has advantages, namely, to address some misconceptions regarding indigenous communities, relate teaching and learning to community knowledge, strengthen learners' identity in society, facilitate the understanding of 'cultural sensitive pedagogies' and acknowledge the role of IT towards economic benefit for all the people in the community (Gumbo 2015:69).

The challenge for technology teachers is to deal with IK as a component of the curriculum where learners are actively involved in obtaining such knowledge and developing relevant skills. Moreover, technology teachers should *immerse* themselves in IK to understand the traditionally situated environment, identify appropriate communal open-ended problems and select suitable learning activities to address problems in indigenous environments. Hence, the aim of this chapter is to conceptualise IT and apply the CHAT (Engeström 2009) as a lens to contextualise IT and perceive teaching-learning activities in problem-based environments within traditionally situated social settings.

Theoretical overview

Technology education and problem-based environments

Technology education was introduced into the South African curriculum with the aim of addressing the need to produce future engineers, technicians and artisans and to develop a 'technologically literate population' to meet global demands (CAPS 2011:8). Technology as a school subject facilitates the development of learners as innovative, creative and critical thinkers, as they need to solve problems using design processes and practical skills. Technology in schools aims to:

1. develop particular skills to solve technological problems
2. enable learners to understand the technological concepts and knowledge and apply these responsibly
3. emphasise people's views on technology in society regarding particular values, attitudes and behaviours (CAPS 2011).

Some features of technology involve the use of authentic contexts substantiated in real life, integration of theory and practice, evaluation of processes and products, and the provision of opportunities to deal with inclusivity and social and environmental issues (CAPS 2011). The management of time, selection of appropriate resources and collaboration in teams are also fundamental in solving technological problems and addressing the world of work (CAPS 2011). The core content areas in technology education comprise the design process (investigation, design, development, evaluation and communication), structures, processing of materials, systems and control, as well as technology in society and the environment, which include IT (CAPS 2011). Although school learners are first exposed to the technology discipline in South Africa as part of Natural Sciences in the General Education and Training (GET) Phase (Grades 4 to 6), in the Senior Phase (Grades 7–9), technology is a subject on its own. Technology is a compulsory subject in the GET and Senior Phase. In the

Further Education and Training (FET) Phase (Grades 10–12), technology is divided into subjects of specialisation, including Mechanical Technology, Civil Technology and Electrical Technology, as well as Engineering Graphics and Design, all as elective subjects (CAPS 2011).

Alamäki (2018:668) highlights that the teaching and learning of technology does not purely focus on memorising and applying technological knowledge but also emphasises skills such as design, invention and the development of solutions for humans. Problem-based learning has gained recognition around the world as a learner-centred pedagogy that has been used for the development of solutions in numerous disciplines (Savery 2015). 'Problem-based learning is perhaps the most innovative instructional method conceived and implemented in education, (Hung 2009:118), as it aims to enhance students' knowledge, problem-solving skills as well as their SDL (Bagheri et al. 2013). Hung (2009) argues that PBL is a distinguished approach to teaching and learning as it personifies human learning because such learning is initiated when a problem is encountered, and learners need to engage in an inquiry process. On this note, scholars concur that PBL provides learners with a driving question or an in-depth investigation as the starting point of learning and promotes active learning (Savery 2015; Servant-Miklos 2018). Moreover, PBL requires engagement in addressing complex problems where learners observe, investigate, decide and reflect on their tasks (Bagheri et al. 2013; Hung 2009; Savery 2015). Solving a problem may involve the development of an artefact where problem- and project-based learning may include aspects of the other (Kolmos & De Graaff 2007). Planning, facilitation and assistance from the teacher are integral factors, while team discussions, member contributions and decision-making involve learners.

Hung (2009) introduced a PBL 3C3R design process model containing core components and processing components. Core components relate to content, context and connection, whereas processing involves research, reasoning and reflection to assist in problem-solving and the development of SDL. Applying IK, the core components involve addressing in-depth content and conceptualisation of technology in natural settings, applying situational knowledge to solve a problem and relating technological IK problems to the curriculum. The processes involve the search for knowledge and reasoning as well as reflection to assist in meaningful engagement (Hung 2009). Regarding IK, processing components involve the facilitation and guidance of learners in understanding the problem of inquiry and search for information by asking the elders in the community, for example. Reasoning involves making decisions and judgements, and drawing inferences relating to technological problems in IK. Moreover, the solving of open-ended problems and reflection are associated with one another. The more challenging a problem is, the greater the need for metacognitive control, feedback and purposeful reflection (Havenga 2011), especially in cultural-historical settings not previously known to teachers and learners.

In this study, problem-based environments involve interactive group activities where members apply technological knowledge and skills in new contexts to solve problems in ecological and traditionally situated social settings. The next subsection addresses the conceptualisation of technology within indigenous environments.

Conceptualisation of technology in indigenous environments

Technology, as a field of study, is described as an applied science, which involves the innovative and collaborative design and development of tangible products and goods with the aim of accomplishing specific objectives and solving real-world problems in practical ways (Engelbrecht & Ankiewicz 2016; Peter 2015). Technology, which is as old as humanity, involves ancient and modern knowledge regarding the development and use of artefacts to address various needs. Borgo et al. (2011) refer to a technological artefact as an entity coming into existence by means of an individual or people carrying out a plan to develop something.

The application of technological knowledge is essential for the design and development of artefacts as usable objects for humanity. According to Alamäki (2018:669), technological knowledge involves 'concepts, principles, theories, and rules'. Jones et al. (2013) and Ankiewicz (2016) accentuate Mitcham's view (1994) that the philosophy of technology comprises the following categories of interest:

- technology as objects, artefacts and products
- technology as a distinctive form of knowledge
- technology as a unit of processes (e.g. development)
- technological involvement in humanity and culture (volition referring to the values, attitudes and beliefs of IK holders).

With reference to the above-mentioned categories, Jones et al. (2013) argue that all these categories have relevance for technology education. The author integrated the views on technology to conceptualise IT in particular, as shown in Figure 8.1 (abbreviated in the diagram are the main aspects of IT. These are outlined in more detail in the description that follows).

The development of *technological artefacts* is related to IT in particular. Indigenous technology involves the development and manufacturing of tangible goods and artefacts as related to specific cultural settings (Gumbo 2015). Peter (2015) mentions that African indigenous science and technology involve the development of tools used by African ancestors. Stone tools such as hand axes and blades are examples of artefacts.

Indigenous technological knowledge denotes a distinctive form of local knowledge (Gandile et al. 2017), inherited from and embedded in societies. Fashola, Osuntade and Shobowale (2010) refer to technologies as the body of knowledge accumulated over time where indigenous technologies are in particular referred to as traditional, local or community innovation. They argue that technology as accomplished by means of traditional knowledge

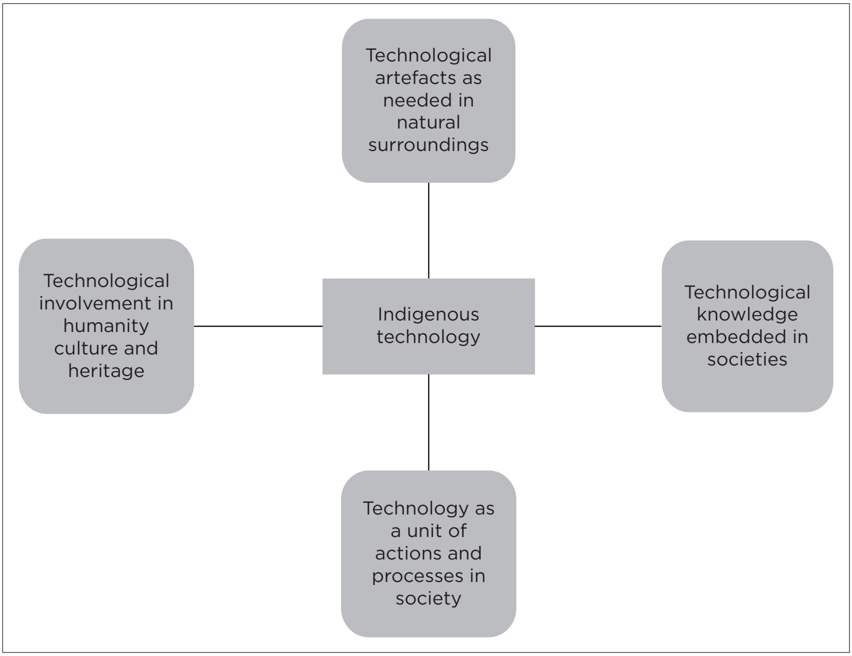


FIGURE 8.1: Conceptualisation of IT.

systems refers to indigenous innovation. Hence, indigenous technological knowledge has a dual meaning. Firstly, it embraces the heritage of accumulated technical knowledge in society, and secondly, it involves innovative knowledge to solve current technological problems by applying traditional knowledge in new situations. People inherently should accept responsibility for knowledge and skills interwoven in societies and the passing thereof to the next generation.

Technology is also described as a *unit of processes* (Jones et al. 2013; Mitcham 1994) and is associated with human behaviours such as actions and processes. On the one hand, technological actions include crafting, inventing and designing, and on the other hand, technological processes involve manufacturing, operating and maintaining. These concepts may include aspects of one another (Mitcham 1994). In terms of IT, traditional artefacts are developed to solve local problems. Development of such artefacts may involve various actions and/or steps (Table 8.1).

Technological involvement in *humanity, culture and heritage* is associated with IK. Technology as a human-inspired activity creates opportunities to be involved in cultural settings.

TABLE 8.1: A framework for problem-based projects in IT.

Steps of problem-based projects	Teacher (S) apply various steps and strategies (T) to achieve the goals (O)	
1. Conceptualise Envisage a distinctive form of knowledge	Facilitate learners in the conceptualisation, understanding and rationale of using IT as a distinctive form of knowledge. Be culturally sensitive and address knowledge gaps	
2. Discuss the problem context Discuss the problem context and refer to a general problem to be solved	Guide learners to obtain knowledge regarding an IT problem in the community. The teacher may use guided questions to assist the learners	
3. Identify knowledge and needs Identify current knowledge and learning needs to solve a problem	Facilitate learners to identify problems in the community and interpret them by asking the following: why, when, what, who, where, how?	
4. Formulate learning objectives Select a particular problem or question and set objectives	Guide learners in the identification of a particular problem in their community to address	
5. Investigate Scrutinise for appropriate resources to address the problem	Guide learners in the selection of appropriate sources, address knowledge gaps in IK and technology, and enable them to make informed judgements.	Reflection
6. Design and develop Focus on the innovative design and development of a solution to the problem	Assist learners in the creative and innovative design and construction of an IT artefact for the community. Discuss end products and provide scaffolding mechanisms. Guide learners to deal with design, development and reflection as means to improve their artefacts	
7. Assess Ensure that the objectives and assessments are aligned and assess each member's responsible involvement in the problem-based activity	Determine each member's contribution towards team activities and assess learning gains in IT. Determine whether learners' development of the artefact addressed the problem of inquiry. Also, assess learners' responsibility towards the community and environment	

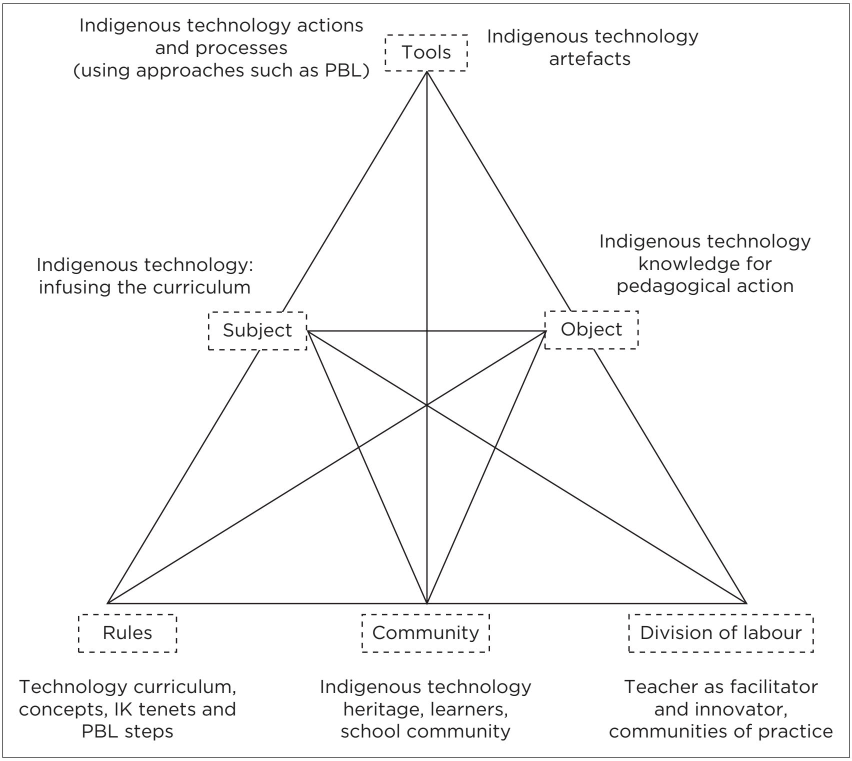
IT, indigenous technology; IK, indigenous knowledge.

Prusak, Walker and Innes (2015) highlight the wisdom of elders regarding decision-making as important where a community strives for consensus regarding traditional values. Mapesela, Hlalele and Alexander (2012) suggest that learning cannot be left to individuals. They emphasise the role of whole-school communities to take responsibility (learners, teachers, school, family and other stakeholders) for creating sustainable rural learning ecologies and enhancing young individuals' learning.

Cultural-Historical Activity Theory as a philosophical lens to contextualise indigenous technology

In this subsection, the author employed the CHAT as a lens to contextualise IT. Cultural-Historical Activity Theory is based on the work of Lev Vygotsky who is known for cultural-historical context in learning, and he emphasises human actions with the aim of dealing with individual and social issues (Herrera 2017). Cultural-Historical Activity Theory comprises particular knowledge, actions and processes, artefacts and products as well as human involvement in cultural aspects (Herrera 2017). Moreover, CHAT is a distinct framework that assimilates human thinking and activities within a traditionally situated social setting, as promoted by Engeström (2009) who coined the construct 'activity system' (refer to Ch. 2). Fundamental to this framework is the focus on the subject, object, tools, rules, community and the division of labour.

With reference to Figure 8.2, CHAT provides for the integration of the philosophical concepts regarding IK in technology (see 'Conceptualisation of technology in indigenous environments' in this book, Figure 8.1 and underlined in Figure 8.2), as there is common ground regarding active and social practices in cultural and historical reality. Applying CHAT also provides for enrichment and elaboration of teachers' views pertaining to IK in the discipline of technology.



Source: Adapted by the author from Engeström (2009).
PBL, problem-based learning; IK, indigenous knowledge.

FIGURE 8.2: Cultural-Historical Activity Theory as a lens to contextualise IT.

The four underlined concepts in Figure 8.2, as based on the section in this book entitle 'Conceptualisation of technology in indigenous environments', highlight technological involvement in humanity, culture and heritage; IT as a unit of actions and processes in society; the development of indigenous technological artefacts; as well as the construction of indigenous technological knowledge as embedded in societies. The dashed rectangles display the main aspects of CHAT (subject, tools, object, rules, community and the division of labour). Hence, IT is contextualised as follows:

- *Subject in the activity system* involves the infusing of IT into the curriculum (use of CHAT on an institutional plane; Rogoff 1995). Thus, the subject is IT.
- *Cultural tools* ('artefacts objectified in material'; Lupu 2011:15) are drivers of active learning, actions and processes (see 'Conceptualisation of technology in indigenous environments' in this book; Hung 2009). Development of artefacts requires the application of pedagogical approaches, such as PBL, as based on a question of inquiry (see 'Technology education and problem-based environments', in this book), and provides opportunities for the practical design and development of indigenous technological artefacts.
- *Object of activity and outcome* develop teachers' knowledge and skills and PCK as attributes in IT to be capable of 'competent pedagogical action' (Lupu 2011:15). Indigenous technological knowledge comprises technology-inherited knowledge (concepts, principles, theories and rules; Alamäki 2018:669) and may involve mechanisms, such as encapsulation, reuse, extension and polymorphism (see 'Technology education and problem-based environments', in this book).
- *Rules* are regulation and integration of actions to guide teachers according to the CAPS (2011:4) for technology education by referring to IK systems 'as a treasured resource of history and heritage'. In addition, the conceptualisation of IT is also required (see 'Conceptualisation of technology in indigenous environments' in this book). Teachers should be guided by the 'rules' (tenets of technology and tenets of IT as well as the 'rules' [steps] underpinning PBL).
- *Community* involves participants in an activity system who share the object and apply the above-mentioned rules. For example, learners, other technology teachers, school community and stakeholders, such as curriculum developers and technology subject advisors, are involved.
- *Division of labour* involves division of tasks, roles and responsibilities. Specific roles of a teacher comprise a teacher

as a facilitator of learning, a teacher as an innovator and a teacher as a lifelong learner, among others. Technology teachers may also work together in communities of practice.

Cultural-Historical Activity Theory at an instructional level: The teaching and learning of indigenous technology

According to Kilpatrick (1986):

> Each age defines education in terms of the meanings it gives to teaching and learning, and those meanings arise in part from the metaphors used to characterise teachers and learners. (p. 7)

Cultural-Historical Activity Theory is employed at an instructional level to characterise teaching and learning of IT in this section. The gist of the activity theory is that it is 'a theory of object-driven activity' (Engeström 2008:3). The third-generation CHAT comprises two activity systems as reflective (mirror images), two-dimensional objects on a plane (Engeström 2009). Cultural-Historical Activity Theory is a tapestry of interwoven and interacting systems and involves multiple viewpoints within a social-historical context. Hence, by using appropriate tools, subjects are the *constructors* of objects in these interacting systems. Regarding CHAT at an instructional level, the teacher guides and facilitates learners, whereas a learner responds by sharing ideas within a group as a safe space for assisting one another's learning, reinforcing team activities and constructively developing members' IT knowledge. The author aims to develop more nuanced understandings of the epistemological border-crossing between IK and technology education.

Cultural-Historical Activity Theory is used in this research as a notional lens to investigate the infusion of IK into the Senior Phase Technology curriculum. The author applied third-generation CHAT to give a juxtaposed and cultural-mediated perspective regarding the instruction of IT, where teaching and learning are both sides of the same coin. Figure 8.3 shows how teaching and learning are taking place between two activity systems, namely, the technology teacher and the learner. The technology teacher (on the left of Figure 8.3) and learner (on the right) are actors or 'subjects' (S) in this formal social context comprising numerous object-driven activities during instruction. The technology teacher needs to deliberately plan for active and responsible student-centred learning. This involves the selection of appropriate strategies ('tools') such as PBL (T) to mediate and facilitate the development of IT artefacts and to guide learners in the solving of local problems ('the object', O). Identification of a community-embedded IT problem is the driving force of

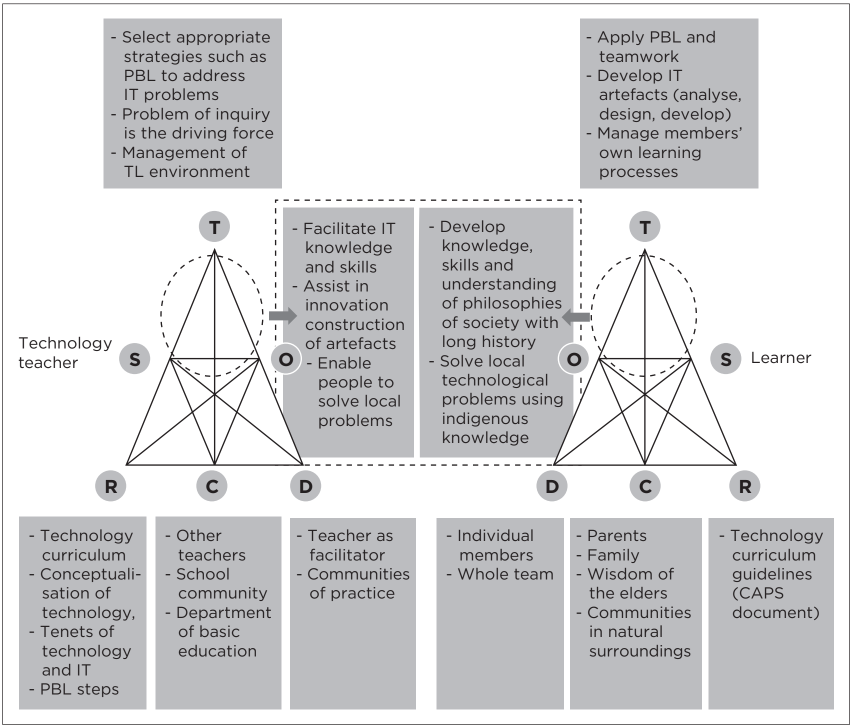


FIGURE 8.3: Cultural-Historical Activity Theory on instructional level: The teaching and learning of IT.

problem-based projects (T) in this activity system. Furthermore, at the bottom of the triangle, the collective activities are shared, directed and influenced by rules (R), the community (C) and the division of labour (D). In IT, the conceptualisation of technology (see 'Conceptualisation of technology in indigenous environments' in this book) as well as the technology curriculum directs activities, and the steps of PBL serve as 'rules' in this system. Other technology teachers, the school community, technology subject advisor and subject specialist are part of the community, whereas the technology teacher may be part of communities of practice (D).

The activity system on the right involves a learner who applies IK when working in a team to develop an artefact and solve local technological problems. Learners need to manage their own learning processes and make decisions while developing a solution to the problem (T). The object of the activity in this system is the team member's development of knowledge, skills and philosophical understanding of society and the ability to solve IT problems. Moreover, a learner may apply mechanisms (see Ch. 8, 'Introduction') to elaborate and reinvent the use of IT to solve local problems. For example, a learner may think about new ways of applying technology to the advantage of the community (polymorphism mechanism). At the bottom on the right, rules involve skill development as outlined in the technology curriculum for the Senior Phase in particular. Assisting learners in indigenous technological knowledge and skill development is the community (C) comprising parents, family and wisdom of the elders, as well as the surrounding communities. The division of tasks, roles and responsibilities involve team members as well as the whole team to achieve the object of activity (O) and outcomes.

The dotted circles between 'S', 'T' and 'O' represent the dynamicity of all activities involved in the *recursive reflection* to achieve the outcomes in both activity systems. In this context, recursive reflection refers to the purposeful action where teachers and learners look back with the aim to 'keep track of what they are doing' (Kilpatrick 1985:8) to become more effective constructors of objects in interacting systems. To rephrase Kilpatrick's (1985) views – reflection requires that we need to move outside our mind to get an insight into what is happening inside our mind. Such reflection needs to continue recursively in problem-based contexts until the problem is solved.

Recursion refers to a function that is defined in terms of itself (e.g. my parents are my ancestors and my parents' parents are my ancestors as well). Similarly, reflection is defined in terms of itself to think about one's own thinking. The purpose is to make better decisions and to learn from previous mistakes when reflecting before, in and on a task. As such, technology teachers as subject specialists are required to facilitate learners' reflective involvement in IK. In this context, learners need to reflect on technological knowledge of history and heritage, technological knowledge of local problems and technological knowledge that is applied in new ways to address challenges. Teachers' self-reflection is also important in terms of the instruction in problem-based environments. The author argues that self-reflection is critical in both activity systems in CHAT to ensure that the outcomes (object) are achieved. In addition, the technology teacher needs to reflect on the appropriateness of tools to facilitate the innovative construction of an IT artefact. The rules (R), community (C) and division of labour (D) should assist in reflective activities.

On the other hand, learners need to reflect on their knowledge and practices obtained as a result of social interaction rather than being transferred between humans (Alamäki 2018). Postholm (2018:429) reveals the importance of reflection in instruction. He suggests that reflecting together with colleagues leads to 'more reflection' and effectively contributes to teachers' learning. This is also true of learners working together to solve problems. Apparently, personal reflection as well as reflecting together may result in the development of rich experiences in the application of technology to solve IK problems in the community. With regard to the learner, he or she should reflect on responsible teamwork in problem-based environments when planning, designing and developing indigenous technological artefacts. Likewise, reflection aims to enable learners to obtain knowledge and skills regarding IT and apply these in the community to address a challenge.

Gretschel, Ramugondo and Galvaan (2015) stipulate that the interaction between the two activity systems may involve some tensions, may elicit some changes and may require reflective practices. For example, a technology teacher aims to include IT in the curriculum, whereas initially, the learners do not see the advantage of obtaining such knowledge. As a result, some tensions may arise between both activity systems. The teacher might discern tensions when explaining the rationale of including IT in the curriculum while learners may develop a broader view, understanding and value thereof. Reflective discourse may enhance the preservation of IT knowledge and skills.

Contextualisation of indigenous technology in problem-based indigenous environments

It is essential that a teacher introduces learners to IK by employing appropriate teaching methods or strategies. According to Hung (2009:119), 'the effectiveness of an instructional method is a result of complex inter-causal relationships of numerous known and unknown variables involved in the instruction/learning processes'. Inter-causal relationships are also part of the activity systems for pedagogical interaction. Activities are performed by actors (teacher and learner as the respective 'subjects'), where both subjects should be dedicated to addressing problems in indigenous environments – the technology teacher as facilitator who pushes the boundaries of the ZPD (Vygotsky 1978) and provides opportunities for learners to obtain indigenous technological knowledge and skills, and the learner who shares ideas within a group to enhance one another's learning and reinforce the group. Problem-based environments enable actors to be interwoven to achieve the aims and outcomes. Hung (2009) highlights scholars' view that learning in problem-based contexts is most effective when it focuses on students' understanding and connection between principles and concepts. The technology teacher (S) needs to facilitate knowledge and skill development, select strategies such as PBL to assist learners in the construction of an indigenous technological artefact (T) and enable them to solve community problems (O) (Figure 8.3). In Table 8.1, a framework for problem-based projects in IT is outlined by referring to the teacher as facilitator.

The left column in Table 8.1 comprises steps as verbs to highlight the active involvement in problem-based environments (e.g. conceptualise and formulate). The mentioned steps are adapted from Maurer and Neuhold (2011) and Hemker, Prescher and Narciss (2017) to incorporate the design and development of artefacts as part of problem-based experiences. These steps also include the main concepts and processes as outlined by Hung (2009), namely, content (Step 1), context (Step 2) and connection (Steps 1 to 7), whereas processing refers to researching (Steps 3 and 5), reasoning (steps 3, 4 and 5) and reflection (all the steps) to assist in the solving of indigenous technological problems.

In the right column, the steps are applied to indigenous technological problems in the community where the teacher needs to guide learners in the solving of such problems. Table 8.1 is aligned with Figure 8.3 and emphasises the continuous reflection between the teacher, tools and objects. Reflection is important to assist learners in developing an artefact to address community problems. On this subject, Ankiewicz (2016) highlights the use of problem-solving and reflective practices in indigenous communities as core activities and approaches when designing artefacts. Furthermore, the categories of interest in the philosophy of technology are aligned (Jones et al. 2013) and applied in IT:

- *Technology as a distinctive form of knowledge*: Conceptualise the understanding and the rationale of using technology in IK (see 'Conceptualisation of technology in indigenous environments' in this book) (Step 1).
- *Technological involvement in humanity and culture*: Guide learners to obtain knowledge regarding an IT problem in the community (Step 2) and support the creative and innovative construction of an IT artefact for the community (Step 6), for example.
- *Technology as a unit of processes*: Various steps, activities and processes are involved in IT (Steps 2 to 6).
- *Technology as objects, artefacts and products*: The design and development of artefacts for the community (Step 6).

Applying indigenous technology in a short learning programme for teachers

Although IK is part of the technology curriculum in the Intermediate Phase, teachers do not necessarily discuss the topic of IK. Moreover, technology teachers are not necessarily familiar with IK in their subject discipline. Thus, extending the learning of technology is essential to include technological artefacts as such artefacts cannot be separated from cultural settings (Gumbo 2015). Consequently, a three-day SLP was developed by NWU to support teachers in science-related subjects by infusing IK in the classroom using CL and PBL approaches (White & De Beer 2017). Technology teachers worked together in an SLP by designing and developing an IT artefact such as a bridge. These teachers used appropriate materials, proper construction techniques, decision-making skills and effective ways to solve the problem on hand. They developed an artefact and assigned responsibilities to members. On this subject, Darling-Hammond, Hyler and

Gardner (2017:8) opined that 'the opportunity for teachers to engage in the same learning activities they are designing for their students is often utilised as a form of active learning'. They elaborate, stating that 'curricular and instructional models and modeling of instruction help teachers to have a vision of practice on which to anchor their own learning and growth' (Darling-Hammond et al. 2017:11).

The following scenario can be given to technology teachers in an SLP: people have to cross a river to get to banks, shops and medical facilities in the town. Furthermore, children need to cross the bridge to go to school and the elderly need to collect their government grants in town. At times, this can also be dangerous, especially when the water level rises after rains. The closest bridge is far away. Crocodiles have also been spotted in the area. As a result, a bridge should be constructed for the community. It must be long enough to allow people cross the river safely without needing to walk on the riverbanks. Technology teachers are requested, as part of an SLP in IT, to develop a bridge artefact using dowel sticks, rope and glue. Teachers need to address this ill-defined problem in small groups; apply problem-solving, critical and reflective thinking; be innovative; and employ particular 'tools' (Havenga 2015). The number of teachers collaborating may depend on the context. Ideally, they can work in groups of two or three on the problem. To give meaning to the learning experience, teachers need to actively construct their own knowledge to address a problem by themselves. Similarly, these are core activities when developing indigenous technological artefacts (Gumbo 2015). This is the practical part of an SLP where teachers obtain the required knowledge and skills by interacting, and experimenting, with one another. In Table 8.1, a framework for problem-based projects in IT is outlined. In Table 8.2, the mentioned steps are applied where teachers need to develop indigenous technological knowledge and skills as part of an SLP.

Consequently, by implementing an SLP, new knowledge and practices are constructed by means of social interaction

TABLE 8.2: Teachers applying knowledge and skills in a SLPs on IT.

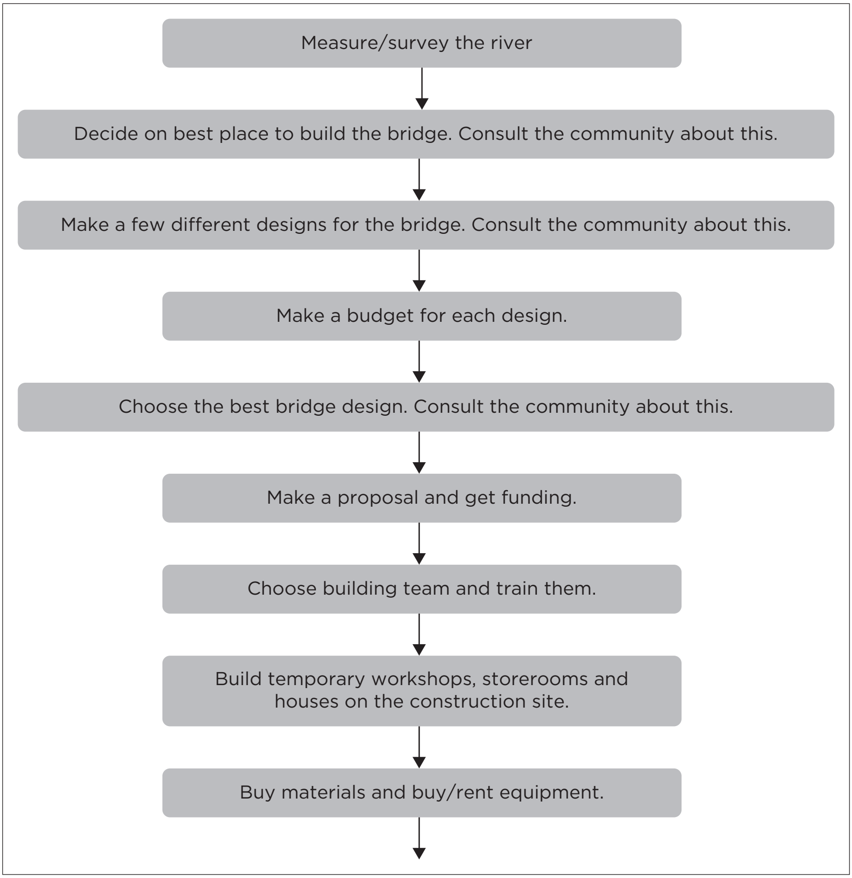
Steps	Teacher (S) apply various steps, strategies (T) to achieve the goals (O)	
1. Conceptualise	Understand the rationale of using IK in the technology curriculum. Teachers reflect on their own knowledge regarding concepts, for example, technology as a distinctive form of knowledge, artefacts, a unit of processes and technological involvement in humanity and culture	
2. Discuss the problem context	Obtain knowledge regarding an indigenous technological problem in cultural contexts as part of communities of practices to explore the problem context or scenario	
3. Identify knowledge and needs	Identify knowledge and the community needs. Some examples are: - People have to cross the river to get to the town (why) -The bridge must be accessible for people with disabilities, elderly people and children (who) - The bridge must be high enough so that it can still be used in rainy weather (how)	
4. Formulate learning objectives	Identification of a particular problem in their community to address. Design and develop a bridge that should be long enough to allow people of the community to cross the river safely without walking on the riverbanks	Reflection
5. Investigate	Search for appropriate sources and make informed judgements. Use books and photos, ask people in the community and the elders. If available, ICTs can be used to search for examples of bridges	
6. Design and develop (e.g. the technological process applied in IK)	Design a prototype bridge for the community. Draw a freehand sketch of this idea. Determine the advantages and disadvantages, reflect and make changes to the design. Develop a prototype of the bridge using, for example, wood, cardboard, glue. Reflect on all activities. Test the strength of the bridge and finally submit the bridge prototype, portfolio and/or report as deliverables	
7. Assess	Determine each member as well as the groups' contribution towards the problem-based task and learning gains. Determine whether development of the artefact addressed the problem of inquiry	

ICT, information and communication technology.

between technology teachers. In addition, the technology teacher may work in various cultural contexts as part of communities of practice to explicitly develop skills concerning IT. The knowledge gained in technology can be applied in multiple cultural contexts and traditional, ecological environments. Implementing an SLP is therefore a learning endeavour for teachers to deal with meaningful tasks in problem-based contexts where they are influenced by culture. The provisional findings from the SLPs offered to teachers in the Northern Cape in 2017 are the following:

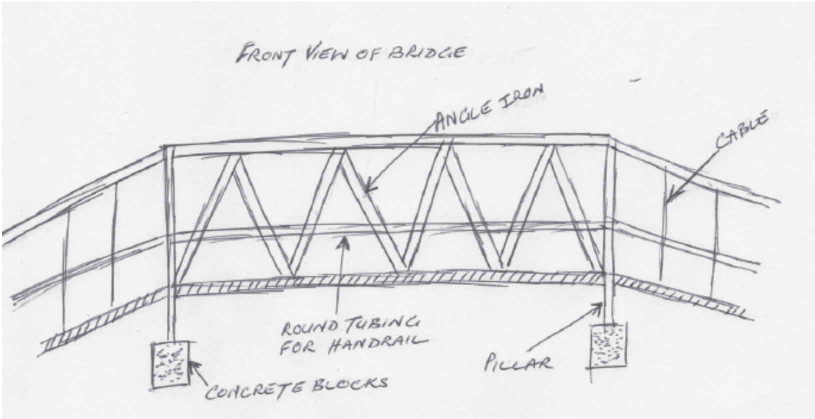
- An SLP can be effective in providing Technology teachers with more nuanced understanding of IT. Abd-El-Khalick, Bell and Lederman (1998) claim that a relationship exists between teachers' views of the nature of the subject (the tenets of technology, in this case) and how they teach. It is therefore essential that in-service teacher education should provide technology teachers with an understanding of the nature of both technology and IK. Regarding the findings, teachers indicated that they have a better understanding of IK in their disciplines (Seleke, Speight Vaughn & De Beer 2018).
- Unfortunately, teachers do not always change their practice (pedagogies) even after attending an SLP. (Refer to Ch. 2, where Mentz and De Beer refer to the 'wash-out effect'). Although there were few examples of good PBL that infused IT after the SLP, most of the technology teachers did not submit a complete portfolio comprising their experiences regarding IK in their subject discipline.
- Technology teachers indicated that there are several systemic factors that negatively affect the transfer of knowledge and skills after the SLP (Seleke et al. 2018). This include the time frames ('pace-setters') in the official (CAPS) curriculum and the pressure of 'teaching-to-the-test' owing to the focus on good throughput in examinations.

Evidence of transfer to classroom after the SLP is the design of a bridge that was constructed by the learners of one of the teachers who participated in the SLP (Figure 8.4 to Figure 8.6; Credit: Portfolio of Mr Aspeling, submitted after the SLP in Calvinia).



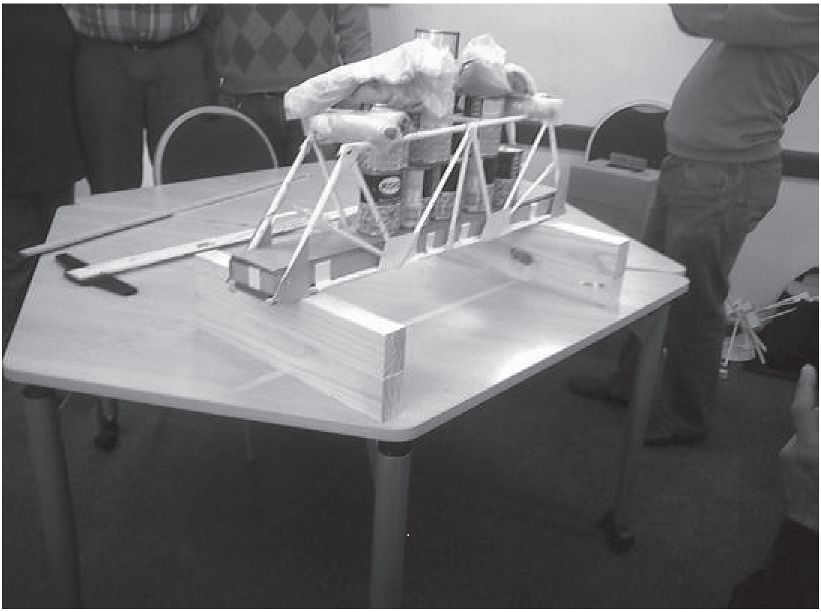
Source: Portfolio of Mr Aspeling, submitted after the SLP in Calvinia.

FIGURE 8.4: Initial PBL steps in the development of a bridge.



Source: Portfolio of Mr Aspeling, submitted after the SLP in Calvinia.

FIGURE 8.5: The design of a bridge.



Source: Photograph taken by W.F. Aspeling, exact date and location unknown, published with permission from W.F. Aspeling.

FIGURE 8.6: Development of the bridge artefact.

Conclusion and recommendations

In this chapter, the author conceptualised IT and structured it with regard to problem-based environments. The CHAT was used as a lens to contextualise IT in problem-based environments. Cultural-Historical Activity Theory was in particular employed to highlight the teaching and learning of IK and to extend the relevance and applicability of this framework where teachers develop IK and design problem-based projects, particularly in the discipline of Technology in an SLP. A particular contribution is the elaboration of CHAT to emphasise the importance of reflection between the subject and tools, and the subject and the object, with the aim to achieve the outcomes of both activity systems. Self-reflection as well as reflecting together may result in the development of knowledge and rich experiences in IT in the community to solve particular problems. Provisional findings from the SLPs offered to teachers were outlined. A few recommendations with regard to the teaching and learning of IT are provided.

Based on the findings, the following recommendations were made for the teaching and learning of IT in problem-based environments:

- The teacher needs to understand the value of integrating IT in the technology curriculum and complement 'Western' technology teaching and learning with IT as embedded in rich cultural assets.
- Teachers should conceptualise IT themselves to enable them to guide learners in the understanding thereof.
- Problem-based learning, when preferred as teaching–learning strategy, should be emphasised in pre- and in-service teacher education to address open-ended cultural embedded problems by applying technical knowledge and skills.
- The limited SLPs offered by NWU should be expanded to provide opportunities for the technology teachers to develop knowledge and skills in IT and to develop more nuanced understandings of the epistemological border-crossing between IK and technology.

Summary

In this chapter, the author firstly conceptualises IT as an essential form of knowledge and skills in natural surroundings, and secondly, the CHAT is used as a lens to contextualise IT in problem-based environments. Cultural-Historical Activity Theory is associated with the work of the Russian psychologist Lev Vygotsky and is used as a framework in this research to understand the knowledge, activities, associations and human thinking when teaching and learning IT in the Senior School Phase in Grade 9. Local knowledge and IK encapsulate the understandings, skills and philosophies of societies with a rich history of interaction with their natural environment. Scholars in the field of IK aim to understand human interaction within this rich heritage. Despite a comprehensive body of research literature in technology education, only a few outputs on IT have been published to date. Addressing this gap, the author attempts to conceptualise IT and to structure it in problem-based environments. Technology is a distinctive form of knowledge and involves processes such as the design and development of artefacts as well as technological involvement in humanity and culture. This chapter is a desktop literature review of scholarly work on IT. This research utilised CHAT with regard to the teaching and learning of IT and elaborates on the role of reflection to achieve the outcomes. The purpose was to extend its relevance and applicability where teachers develop IK and design artefacts particularly in the discipline of Technology in an SLP. This chapter also briefly reflects on provisional findings that emerged from data collected after a SLP regarding IK that was offered to Technology teachers in the Northern Cape.

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Chapter 9

The use of puppetry as pedagogy to teach indigenous knowledge

Lounell White
School of Mathematics, Science and Technology Education, Faculty of Education, North-West University, Potchefstroom, South Africa

Susan Bester[a,b]
[a]Self-Directed Learning, School of Commerce and Social Sciences in Education, Faculty of Education, North-West University, Potchefstroom, South Africa
[b]Research Unit Self-Directed Learning, Faculty of Education, North-West University, Potchefstroom, South Africa

Tswakae Sebotsa[a,b]
[a]School of Mathematics, Science and Technology Education, Faculty of Education, North-West University, Potchefstroom, South Africa
[b]Research Unit Self-Directed Learning, Faculty of Education, North-West University, Potchefstroom, South Africa

Introduction

This chapter focuses on the affordances of puppetry in the classroom. Puppetry is a form of storytelling and thus is well aligned with the oral tradition of IK (Shava 2016). We argue that

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puppetry is an excellent pedagogy to teach IK in the classroom, as it taps into a central tenet of IK as epistemology. The chapter draws on research data on the use of puppetry in the Natural Sciences (Life Sciences and Physical Sciences) and Social Sciences classroom at a South African university.

Regrettably, the Western curricula excluded IK for decades (Whatman & Duncan 2005). Unfortunately, as a result, the younger generation has lost interest in IK (Msuya 2007). Owing to this marginalisation or exclusion of IK from the Western curricula, the contextual circumstances of school learners were not considered (Shava 2016). Makari and Kasanda (2013) argue for a connection between theoretical knowledge ('Western' knowledge) and its practical application in communities that are predominantly indigenous in nature.

Shava (2016) is of the opinion that the epistemological border-crossing between IK and the Western curriculum could assist in decolonising the curriculum. Shava states that areas should be identified where IK can be infused into curriculum themes. This would enrich the curricula, and as the lived experiences of learners are considered, learners might experience the curricula as more meaningful and relevant, thereby promoting the attainment of affective outcomes (refer to Ch. 4).

Since 2011, South Africa has attempted to infuse IK into the curricula of various subjects. Indigenous knowledge, among others, is mentioned as one of the principles that should underpin education (DBE 2011a). Unfortunately, research (e.g. Cronje, De Beer & Ankiewicz 2015; De Beer 2016; White & De Beer 2017) indicates that most often only lip service is paid to IK in most classrooms. Abah, Mashebe and Denuga (2015:672) state that 'while Western science offers broader appreciation of context beyond the local level, indigenous knowledge offers depth of experience in a local, culture-specific context'. From an ESDC perspective, learning cannot take place in isolation (Hardy-Vallée & Payette 2008) (this is discussed in more detail in Ch. 4). According to Maxwell and Chahine (2013:67), effective learning takes place in an atmosphere of a learner's 'existing knowledge, background and environment'. Dei (2016) alluded to the importance of background knowledge that learners bring to the classroom when entering the school, which includes IK from a specific cultural group. Teachers should therefore tap into the knowledge of learners to contextualise the curriculum when teaching a specific topic (Dei 2016). However, this is easier said than done. The rich cultural diversity in South Africa can pose challenges, as learners from different cultural groups are present within a single classroom, which makes it difficult to decide which IK to infuse into the classroom (De Beer & Mothwa 2013; George 2011).

The objective of this research was to facilitate the border-crossing between Western knowledge and IK by introducing puppetry as a vehicle to portray IK storytelling. Realising that teachers are often not sufficiently trained to infuse IK into their lesson plans, NWU has infused IK elements, and such epistemological border-crossing, into its pre-service teacher education programme. In this chapter, we focus on the lived experiences of student teachers who engaged in puppetry in selected subject methodology modules. The focus of this chapter is therefore only on Life Sciences, Physical Sciences and Social Sciences (DBE 2011a, 2011b, 2011c) and the lived experiences of student teachers in using puppetry as a pedagogy to teach IK.

■ The tenets of the nature of science and indigenous knowledge, and the affordances of puppetry as relevant pedagogy in Natural Sciences

Some teachers still have naïve understandings of the NOS in that they have more positivist outlooks on science, which involve the perception that scientific knowledge can be gained only through observations and experimentation (Ecevit, Yalaki & Kinger 2018). Adedoyin and Bello (2017) confirmed these perceptions in their research on student teachers and expressed concern that, if these misunderstandings prevail, it would again be carried over to another generation of learners. Lederman et al. (2002) gave a good overview of the tenets of the NOS, which includes its empirical nature, tentative nature, well-established theories and laws. Our research, however, focussed on other tenets, such as the subjectivity of scientific knowledge, the social and cultural context of the NOS as indicated by Sormunen and Köksal (2014), as well as the tenet that human creativity and imagination play a role in science (Cronje et al. 2015).

Indigenous knowledge can be infused into the Science curriculum. As Cronje et al. (2015) indicate, Western knowledge systems and IK systems need not necessarily be in conflict. The space where IK and Western ways of knowing connect and overlap can be understood as the 'cultural interface' (Nakata 2002). This can be a contested space but can also be a space where different ways of knowing work together synergistically. Cronje et al. (2015:323, 324) have shown that there are (despite several differences) many shared tenets when the NOS and the NOIK are compared. Both science and IK are empirical (although IK also has a metaphysical component), both are tentative (and subjected to change), both are inferential, both are creative and both are socially and culturally based. This could facilitate science teaching that acknowledges learners' knowledge and culturally based ways of thinking, which will almost certainly unlock potential to make science more meaningful to them (Cronje 2015).

The affective domain of human thinking in science education is a reason for the poor performance in science that is often overlooked (De Beer 2016). Dubinsky, Roehrig and Varma (2013) showed us that experiences with an emotional stamp are more likely to be committed to long-term memory.

Infusing IK into curriculum themes can be illustrated with a few examples. In Physical Sciences, for instance, traditional leather tanning could serve as a brilliant way of introducing endothermic reactions in the classroom (De Beer 2015; Zaruwa & Kwahe 2014).

The second example is that of indigenous alcohol fermentation. Whisky-like alcohol is produced by the indigenous people of southern Africa by fermentation of sugars (in millet, maize and fruits such as marula). The fermentation reaction of the sugar obtained from the ingredients or sugar cane is glucose (sugar) + enzyme ==> ethanol + carbon dioxide. This can be chemically represented as follows: $C_6H_{12}O_{6(aq)}$ + (enzymes) ====> $2C_2H_5OH_{(aq)} + 2CO_{2(g)}$. CAPS Grade 10–12 Physical Science (DBE 2011b) mentions two basic links to alcohol fermentation. Firstly, the preparation of alcohols via different reactions of which the substitution's reactions are the basic preparation method. Secondly, the principle of fractional distillation – the separation of liquids based on different boiling points – is illustrated by fermentation. This IK example is also suitable to contextualise the Life Sciences curriculum for learners when the topic of anaerobic fermentation is offered. In Life Sciences (DBE 2011a), the importance of medicinal plants can also be infused into the curriculum. Medicinal plants have been used by various IK holders to treat various diseases worldwide. South Africa is no exception with its rich endemic plant species and herbalists and '*muthi*' doctors who have an in-depth knowledge of the uses of these plants. Different parts of the plants, such as roots, bulbs, bark, leaves, flowers, fruits and seeds, can be used for medicinal purposes (Van Wyk & Wink 2012). Indigenous knowledge has a strong empirical side to it, and authors such as De Beer and Whitlock (2009) indicated how learners could engage with IK utilising the 'tools' of science and explore the tenets and nature of Natural Science. These authors showed how a Kirby–Bauer technique could be used in the science classroom to test the antimicrobial properties of medicinal (*muthi*) plants (refer to Ch. 4 in this regard).

However, such activities do not address the holistic nature of IK, as IK also has a metaphysical character. Moreover, Gorelick (2014) refers to metaphors that characterise IK and that knowledge is often encapsulated by such metaphors and stories. This metaphysical and creative aspect could also be addressed in the science classroom by engaging puppetry as a storytelling medium (which is the focus of this chapter), where learners can discuss whether certain aspects of IK should be seen as pseudoscience (White & De Beer 2017) or whether we have a naïve understanding of IK. For instance, De Beer and Van Wyk (2018) discussed the use of *impinda* (*Adenia gummifera*), which was traditionally used to 'expel evil spirits'. Clinical tests have shown that *impinda* has a strong antimicrobial activity that can kill bacteria. For IK holders who were not familiar with the word bacteria, an 'evil spirit' caused the illness and their solution was to use *impinda* as a cure (refer to Ch. 4).

Puppets and storytelling can provide a vehicle to infuse arts and science and thereby address the affective domain. Albert Einstein, who also was a violinist, is a good example of the complementarity of art and science. He spoke about the importance of music in helping him become a creative thinker. Albert Einstein (Einstein, Calaprice & Dyson 2010) has been quoted saying:

> Where the world ceases to be the scene of our personal hopes and wishes, where we face it as free beings, admiring, questioning, and observing, there we enter the realm of art and science. We do science when we reconstruct in the language of logic what we have seen and experienced: we do art when we communicate through forms whose connections are not accessible to the conscious mind yet we intuitively recognize them as something meaningful.
>
> *For a magazine on modern art, Menschen, Zeitschrift neuer Kunst (19 February 1921).* (p. 234)

Leonardo da Vinci, renowned for his paintings, also had scientific aptitude (Kemp 2006). These individuals demonstrated the tenets of art and science in their work. Some researchers see science and art sharing many similar tenets (Yakman & Lee 2012). These tenets form the basis for a STEAM (Science, Technology, Engineering, Arts and Mathematics) framework, and Yakman and Lee (2012) are of the opinion that fusing arts into science results in learners becoming more flexible in their thinking and in the process of adopting intellectual skills and other attitudes that make them more adaptable to life.

The Lincoln Center Education (2018) identifies a number of capacities for imaginative thinking, namely:

- Notice deeply – identify and articulate layers of detail in a work or artefact.
- Pose questions – use questions persistently to reposition thinking and generate curiosity beyond conclusions.
- Make connections – relate what you notice to your own knowledge and experience, and other people's perspectives.
- Identify patterns – find and analyse relationships among details.
- Embody – explore ideas or objects of study physically.
- Empathise – respect diverse perspectives, feel for the experiences of others.
- Live with ambiguity – understand that issues have more than one interpretation.
- Create meaning- form your own interpretation.
- Take action – realise what you imagine, in the world and in your community, based on what you have learnt.
- Reflect and assess – pause and examine what you have done. (p. 4)

We believe that the above capacities are equally relevant in science and in arts, and that puppetry could be a good vehicle to address these capacities.

Infusing arts into science can be done by contextualising knowledge for learners using puppetry to help storytelling, which could be utilised in the science classroom to make science more interesting to learners (De Beer 2016). Chinyowa (2001) argues that African storytelling is a powerful pedagogical tool for communicating people's knowledge and wisdom.

■ Cultural artefacts and the affordances of puppetry as relevant pedagogy in Social Sciences

In this section, the concept of *culture* is discussed, because stories and storytelling are some of the aspects of culture, and puppetry is a corollary thereof. Therefore, it is necessary to give an overview of the main aspects of culture.

Idang (2015) and Mawere (2015) argue that cultural artefacts are generally divided into tangible culture and intangible culture. In Natural Sciences, IK can be infused into the classroom by addressing the NOS and the NOIK. Social Sciences, on the other hand, can instil IK by concentrating on cultural artefacts. The tangible cultural relics refer to material objects such as historical buildings, monuments, statues and declared heritage sites. Clothing, beadwork, fine art as well as architectural evidence and palaeontological remains are also tangible artefacts. Other elements of culture such as traditional songs, music, food and craftsmanship are regarded as intangible cultural artefacts. Traditions, proverbs, storytelling, folktales, rituals and festive events are also included in these. Belief systems such as religions are also considered as an intangible cultural artefact (Lenzerini 2011) (refer to Ch. 4 where the authors indicate how multimodal learning supports the doctrine of ESDC).

Storytelling can then be considered as an artefact, and according to Tobin and Snyman (2007), the word *story* (meaning an account of incidents or events) has its origins in the 13th century, with roots in both French and Latin. In this context, Deacon and Stephney (2005:24) state that ‘stories bring the community and its members together in a shared understanding of the world and their place in it’, because through stories, one learns about identity, history, society and the world (Cherry 2017).

In Social Sciences, there is a strong focus on the rich cultural diversity of South Africa – isiZulu, isiXhosa and Khoi-san cultures – to name but a few. Examples in Social Sciences (DBE 2011c) (in the History section) where puppetry and storytelling can be applied as a pedagogical tool are first addressed in Grade 4. Here, the curriculum content addresses the history of local areas through stories and interviews with people. The Grade 5 curriculum focuses on stories from hunter–gatherers and herders that portray the Khoi-san culture and beliefs. Furthermore, the rich heritage of Khoi-san rock paintings can be used as a form of storytelling, as these paintings depict their customs such as hunting and clothing (Eastwood 2006; Seroto 2011). (Some of the vignettes in Chapter 4, such as the one on the black-shouldered kite, could also be a good script for puppetry.)

Teaching methodology

As storytelling through puppetry could be used to infuse IK into both the Natural Sciences and Social Sciences curricula, the value of storytelling and puppetry as teaching methodology in the curriculum was the focus of this research.

Storytelling

Storytelling can be regarded as the earliest form of teaching. Before written language was developed, people told stories to preserve history, traditions and taboos (Dujmovic 2006). Thus, storytelling is an important part of human culture, and the past has always been organised and shaped through stories (Hawkey 2007). African storytelling was also used for educational purposes and portrayed the African philosophy (Chinyowa 2001). It was used to interpret the universe, to resolve natural and physical phenomena, to teach morals, to maintain cultural values, to pass on methods of survival and to praise God (Utley 2008). African storytelling was a ritual that usually took place in the evening after a hard day’s work. The villagers would gather around a fire and settle down to listen to stories (Tuwe 2016). Storytelling therefore was the medium of choice to preserve their history, traditional culture, beliefs and ritual ceremonies (Namulundah 2011).

Repetition was an important characteristic of African oral storytelling. The audience partook in the ambience of these stories because they imitated the motions and repeated the words of the storytellers. Repeating the stories facilitated the understanding of these stories, which also enabled the audience to recollect these stories at a later stage. (Refer to the section on mnemonic networks in Ch. 5). The purpose of these stories was also to transmit important features of their cultural ways to other members of the community (Utley 2008). It also provided the children with the opportunity to play active and interactive roles in storytelling (Namulundah 2011).

Research draws attention to the different values and benefits of storytelling. Storytelling is not always a mere presentation but is acknowledged as a living art, as the storyteller uses words, sounds, songs, language patterns, hands and facial expressions (Anderson 2005). Stories could also contribute to recording and expressing feelings, attitudes and lived experiences (Tuwe 2016), which lead to a better understanding of the thoughts and feelings of others (Paul 2012). Therefore, stories also engage learners on a rational and emotional level (Sole & Wilson 2002). Stories can be used as a communication tool through which complex ideas can be presented in a simple, more memorable form. In other words, stories and storytelling can be a vehicle to teach and learn new content. Thus, learning with stories enables learners to understand, recall and remember the learning content in meaningful and relevant ways (Scholtz 2003).

Imagination is central to storytelling activities (Agbenyegaa, Tamakloeb & Klibthongc 2017). In this regard, Huff (2000) considers puppets as multisensory tools in storytelling, which stimulate imagination and encourage creativity, through which learners' reading and listening experience could be enriched. Vygotsky (2004) indicates that, during storytelling, children can imagine the characters they cannot see, can conceptualise what they hear from storytellers and can think about what they have not yet experienced. Denning (2000) suggests that stories provide the ability to communicate naturally, clearly and truthfully, while Swap et al. (2001) point out that stories stimulate interaction.

Another benefit of stories is that stories provide an effective means of sharing knowledge about different cultures, language and traditions. Within the South African context, sharing of stories is an ideal way of both affirming cultural diversity and discovering our common humanity (Tobin & Snyman 2007).

The function of storytelling has been identified as the mediation and transmission of knowledge and information across generations (Chinyowa 2004), which include voice and gestures, and can be linked in the modern world with puppetry, which can engage learners as *Homo ludens* (Huizinga 1955), which in turn fosters a PoP and provides teachers with the scope to be creative and artistic in their teaching.

Puppetry as a teaching methodology

Storytelling has a rich tradition and is considered as one of the original teaching forms (Liang et al. 2017). Storytelling is central in puppetry, and De Beer, Petersen and Brits (2018) explored the epistemological border-crossing, using puppets to infuse art and drama into the classroom. Puppets can be used effectively as a pedagogical tool in education. Tzuriel and Ronit (2018) argue that puppets can be used efficiently for learners with special needs, as teaching with puppets elicits a higher level of mediation strategies than teaching without a puppet. In nursing education, Tilbrook et al. (2017) reported that puppets were used successfully in acute care paediatrics, while Reid-Searl et al. (2017) described the use of puppetry for play therapy. Pearce and Hardiman (2012) illustrated that puppetry can also be used at the tertiary level by using the method of 'Hot Seating through Puppetry'. This method promoted engagement among business students; puppets were used to challenge students to explore and discuss contemporary marketing issues, including controversial products and ethics.

At the school level, puppets were used in subjects such as Biology (Life Sciences), Natural Sciences and Mathematics. Keogh and Naylor (2008) described how puppets were used in Mathematics lessons to provoke dialogue and discussion. Belohlawek, Keogh and Naylor (2010) used the Talk in Science project, which focussed on using puppets, to engage children in conversation to develop their thinking about scientific concepts in an inquiring, explorative approach. This project motivated and engaged teachers to link literacy with science in their teaching and learning practices. Borota et al. (2007) also highlighted the importance of learners making their own puppets.

Puppets could be used to establish a less intimidating communication space, as they are non-dangerous mediators that can compare, compete and participate in dialogues (Borota et al. 2007). Puppets are therefore considered as non-judgemental and thus become confidants of children who might find it difficult to express themselves (Tubbs 1993).

Addressing the affective domain through puppetry as a teaching methodology could provide a safe space for learners to address emotional and controversial issues. According to Serame et al. (2013), the best word to describe this safe space is the German word *geborgenheit* (which can roughly be translated as a feeling of security). According to them, *geborgenheit* is particularly important in the teaching and learning environment to ensure that learners feel mentally and physically safe. Instituting puppets to enhance the affective domain in a subject introduces a creative element into teaching (Lin 2014). Research conducted by Sellman (2015) indicates that an environment of trust is created by bringing artists into traditional education contexts. This provided a safe space for learners where they could share their ideas and develop their own skills and critical thinking.

Self-directed learning

Both puppetry and the infusion of IK can enhance SDL in learners. De Beer et al. (2018) describe how puppetry can be used in the Life Sciences classroom to facilitate the epistemology border-crossing between Western science and IK using CL techniques. Both PBL and CL – if implemented wisely – could enhance SDL (Barrows 1996; Garrison 1997), as it is expected of learners that they evaluate the process and outcomes of their own learning by setting their own learning goals and identifying their own resources to accomplish their goals (Knowles 1975).

Douglass and Morris (2014) iterate the tenets of SDL in their research in that they indicate that learners should take ownership of their own learning so that they experience a sense of autonomy when they succeed. These authors also indicate that intrinsic motivation is very important in the SDL process.

Using these elements identified by Knowles (1975) in SDL as a process, De Beer and Mentz (2017) indicated various practices from IK holders that can be regarded as SDL, for example, the use of medicinal plants in the Khoi-san community. It was mentioned earlier that the use of medicinal plants can be infused into the Life Sciences curriculum, and this topic was also addressed during this particular research. The Khoi-san community demonstrate SDL, according to De Beer and Mentz (2017). They showed evidence of taking responsibility for their own learning in solving authentic problems (e.g. identifying suitable plants which can cure a specific illness) – for instance, *Sutherlandia frutescens* (cancer bush) was used to treat diabetes, high blood pressure, stomach problems and common cold (De Beer 2012). The Khoi-san community were able to expand their knowledge as they later also used *Sutherlandia frutescens* to treat AIDS (De Beer 2012). De Beer and Van Wyk (2011) developed an ethnobotanical index to determine the ethnobotanical knowledge of the Khoi-san in different age categories. Their research showed that young people were able to identify edible plants and were able to harvest them sustainably. Furthermore, older people were also able to identify plants to treat different illnesses. De Beer and Mentz (2017) are of the opinion that the Khoi-san community were able to identify plants according to their own needs, which changed as they became older (refer to Ch. 3).

De Beer and Mentz (2017) used the data of the EKI and claimed that PBL among the Khoi-san people were needs-based. The use of medicinal plants by the Khoi-san is linked to solving authentic problems. Barrows (1996) showed that PBL has the potential to enhance SDL. De Beer and Mentz (2017) indicated that the Khoi-san community were responsible for their own learning.

As soon as a need arises, for instance, hunger or an illness, members of the community must be able to identify their own learning needs (which plants are appropriate?), identify suitable resources (which plants can be used to address their hunger pangs or cure an illness?) and, lastly, identify strategies to harvest the plants and evaluate if the plants are suitable to suppress their hunger or cure an illness (refer to Ch. 3).

This chapter therefore showcases research conducted with student teachers on infusing IK into their classrooms using storytelling by means of puppetry, in an attempt to enhance SDL in the classroom. Specific curricula topics are suitable to infuse IK, and student teachers were sensitised to utilise such opportunities.

Research questions and research methodology

A qualitative research design

This research focussed on student teachers completing a subject methodology course in either Life Sciences or Physical Sciences (both subjects at the FET level) and Social Sciences (which targeted the Senior and Intermediate Phases). This research initially focussed on Life Sciences student teachers and was later expanded to include student teachers specialising in Physical Sciences and Social Sciences as well.

The chapter reports on the perceptions of student teachers on the use of puppetry as a vehicle to portray IK storytelling. The following questions directed the research:

- What are the perceptions of student teachers on the use of puppets within their teaching methodologies?
- How can IK be infused into the curriculum by using puppetry?

This research followed a qualitative design, and a convenience sampling method was used as data were obtained from student teachers during a normal class period. Ethical considerations were taken into account, and ethics approval was obtained from the university. An independent person (colleague) explained the research to the student teachers, after which they willingly completed the consent forms. Student teachers were also informed that participating in the research was voluntary, but they still had to participate in the class activities, as they formed part of the normal module outcomes. Only student teachers willing to participate in the research completed the pre- and post-questionnaires as well as the reflective notes.

Student teachers in both the Life Sciences and Physical Sciences methodology modules first completed the pre-questionnaire on infusing IK and puppetry into a lesson. Thereafter, a short Power Point presentation was used to facilitate a discussion on IK and how puppetry can be used as pedagogy in this regard. The Life Sciences presentation focussed on the usage of indigenous plants as medicine, while Physical Sciences focussed on indigenous beer-making techniques (anaerobic respiration and the chemistry involved). Both groups then watched a short puppet show. In addition, the Physical Sciences group performed an experiment that simulated African beer-brewing [*Umqombothi*].

In Social Sciences, student teachers initially watched a video of a puppet show. The value and use of puppets as a teaching methodology in Social Sciences were then discussed. This was followed by a discussion on which CAPS topics (DBE 2011c) in Social Sciences are suitable to infuse IK into the curriculum.

Both Physical Sciences and Life Sciences student teachers discussed – using the De Bono's thinking hats (De Bono 2016) technique – the feasibility of using puppets in their classrooms to introduce concepts of IK. Using this technique as a CL strategy enabled the student teachers to discuss the topic from different perspectives.

Student teachers in Physical Sciences and Life Sciences then completed a post-questionnaire in the classroom to determine whether their perceptions had changed with regard to using puppetry to infuse IK into their lessons. Student teachers in Social Sciences only completed one questionnaire (after the development of scripts and the puppet shows) to establish their perceptions of using puppetry as methodology to infuse IK into a Social Sciences classroom.

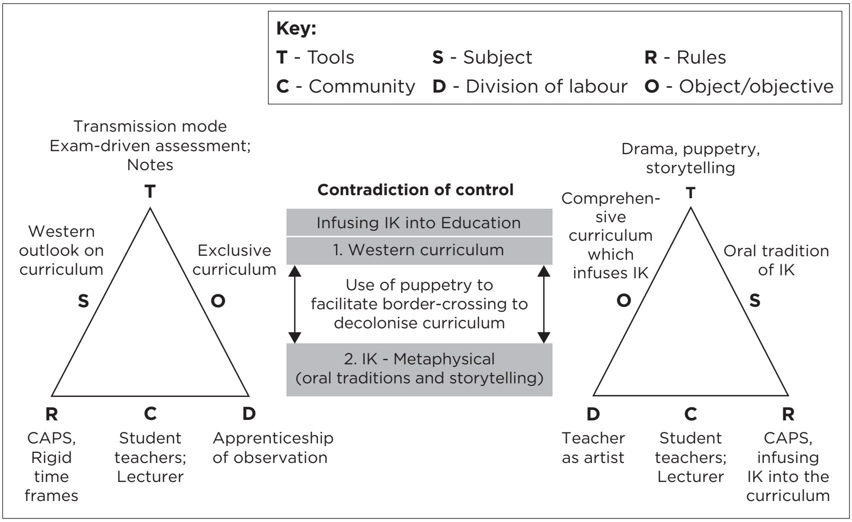
Lastly, the Life Sciences and Social Sciences student teachers planned and presented puppet shows specifically for their subjects. This placed a high premium on SDL. Life Sciences student teachers focussed on indigenous plants, while those in Social Sciences concentrated on the diversity and heterogeneity of the South African people. Student teachers had to write their own scripts, make their puppets and then have a puppet show, which was videotaped. Student teachers were asked to write reflective notes about the feasibility of using puppets in their classrooms.

Data gathered from student teachers' completed questionnaires, discussions using De Bono's thinking hats, reflective notes and data scripts of puppet shows were individually transcribed and coded for the three different subjects. Codes were then arranged into emerging themes (Saldaña 2013).

Research lens: Third-generation Cultural-Historical Activity Theory

This research used the third-generation CHAT as the research lens to analyse the data (Engeström 1987) (refer to Ch. 2 for a detailed description of using CHAT as a research lens). In this research, CHAT was used on a systemic, institutional plane (Mentz & De Beer 2017) where the subject is a system rather than a person. This is illustrated in Figure 9.1.

Engeström (2001) indicates that two interrelating activity systems allow the researcher to study various perspectives as well as the interaction between the two activity systems. In this research, activity system 1 refers to the Western outlook on the curriculum, while activity system 2 focuses on the oral tradition of IK and its use of 'tools' such as drama, storytelling and puppetry in the classroom. One of the underlying principles of an activity



Source: Adapted from Engeström (2001).

FIGURE 9.1: Comparing the Western perspective on the curriculum with the oral tradition of IK through the perspective of CHAT.

system is to identify underlying tensions (Engeström 2001) that can influence the achievement of the object. These 'tensions' can either be potential conflicts within the system or it can identify innovation and improvement within the activity system, which is necessary for growth and development within the system. Breidlid (2013) is of the opinion that, by using CHAT as the research lens, the multifaceted interactions between IK (and the traditional tools such as storytelling and puppetry) and a Western outlook on the science curriculum can be researched. Processes that can contribute to changes both at the institutional and individual level, which can lead to transformation, can be studied and analysed using CHAT (Breidlid 2013).

This research highlights the contradiction of control (McNeil 2013) when comparing the Western outlook on the curriculum with the oral tradition of IK. Student teachers engage with CAPS (2011a, 2011b, 2011c) in their respective subjects, but these documents do not explicitly indicate how to infuse IK into their subjects. By introducing puppetry and storytelling to the student teachers as teaching methodology, it addressed the objective of this research to facilitate the dual border-crossing between Western knowledge and IK (Cronje 2015) and between arts and science (Petersen & White 2018).

Activity system 1

The subject of this activity system is the Western perspective of the curriculum, which is governed (the rules) by CAPS (DBE 2011a, 2011b, 2011c) in the South African context. Rigid time frames known as pace-setters are provided, which must be followed in order to complete the curriculum in time. In order to adhere to the rigid time frames of the curriculum and policy documents, transmission-mode teaching (e.g. lectures) is often used as a tool. Ramnarain and Schuster (2014) have shown that teachers, especially in previously disadvantaged schools in South Africa, predominantly use ‘chalk-and-talk’ approaches owing to the pressure on them from school management and parents that children perform well in summative assessment opportunities. Student teachers (the participants in this research) were all learners in such teachers’ classrooms (see the notion of the ‘apprenticeship of observation’ in the next paragraph), and therefore, they tend to use the same tools during their school experience.

Student teachers and the lecturer form part of the community where the student teachers are introduced to a variety of methodology practices. Student teachers were all part of a school system and had the preconception that they were familiar with teaching. This is known in education as the ‘apprenticeship of observation’, a term coined by Lortie (1975). These student teachers therefore come with at least 12 years of ‘baggage’ into their teacher education, and it is extremely difficult to assist them in breaking the cycle of transmission-mode teaching. This is also of particular importance in the context of this research on puppetry, as few students were exposed to such pedagogies in school.

The division of roles (labour) concerns the student teachers who alternate their roles between that of a student and a teacher. On the one hand, they take on the role of a student when they receive tutoring to become teachers, and on the other hand, they switch roles to that of a teacher when they have to develop activities they can use in their future classrooms. The prescribed course introduced student teachers to the different roles of a teacher, such as the teacher as a reflective practitioner (Gravett & De Beer 2016), the teacher as a facilitator of learning (De Beer & Gravett 2016) and the teacher as an interpreter of the curriculum (Du Plessis 2016).

Activity system 2

Activity system 2 included elements of activity system 1 as CAPS still govern the activity system. In activity system 2, the oral tradition of IK (subject) is infused into the teacher training curriculum, which expands the object of the activity system to a more comprehensive curriculum as IK can contextualise the content for the learners (in this case, the student teachers) (Breidlid 2013).

To expand the curriculum, tools used in this activity system included drama and storytelling. Introducing these tools can address the metaphysical aspects of IK, as puppets were used to convey IK stories. Ogunniyi (2011) is of the opinion that the worldview of teachers (and in this instance, student teachers) should be expanded to include other worldviews such as IK, which should be infused into their classrooms.

Student teachers and their lecturer still formed part of the community in this activity system, but the division of labour now broadened to include the teacher as an artist (Graham & Rees 2014), which included creative pedagogy in the classroom in this activity system.

Findings and discussion

As CHAT is a barometer of tensions, the following tensions were evident in the two activity systems. These tensions are discussed under the following four themes. As the same themes emerged when analysing the data from student teachers for Life Sciences, Physical Sciences and Social Sciences, the discussion includes the findings of all the students, and no distinction is made between feedback of students of the different subjects.

The first two themes indicated that student teachers were unable to use puppetry to facilitate border-crossings between science and IK as well as between arts and science.

Many student teachers were of the opinion that puppetry and storytelling is an inappropriate pedagogy for high school learners

Many student teachers indicated that puppetry is an inappropriate pedagogy for high school learners. Perceptions of student teachers were that introducing puppets in a classroom might lead to disruptions in class as learners might make jokes and regard puppets to be childish, which is evident from the following quote by a student teacher:

> Puppetry is not something that can be taken seriously by anyone above the age of 10 years let alone high school students. If there is anything a teacher can focus on, it should be technology in the classroom, but using puppets sounds quite insane to be honest. (Student teacher, undisclosed gender, date unknown)

This indicates a tension within the division of roles and between the 'division of labour' and the 'object'. Student teachers still saw their role as teachers from the observations of their own teachers – the 'apprenticeship of observation' as described earlier (Lortie 1975). Student teachers were used to the transmission-mode of teaching (Ramnarain & Schuster 2014) and were not exposed to puppetry, which might be an unfamiliar concept to them. This was emphasised by another student teacher who said, 'some learners will not adapt to the use of puppets in the classroom as they are used to pen and paper and chalk board' (student teacher, undisclosed gender, date unknown).

Tensions between the tools and object were identified. Some student teachers believed incorporating puppetry into their teaching methodology will distract their learners from the actual content of the lesson, as one student teacher indicated 'learners will look more at the puppet than paying attention' (student teacher, undisclosed gender, date unknown). Another student believed that 'when there is an incorporation of fun in the classroom, learners get carried away and their focus shift' (student teacher, undisclosed gender, date unknown). Puppetry was viewed as an inappropriate methodology in the exam-driven education system, saying 'I do not think it's appropriate for a class of 30 learners which almost write record exams' (student teacher, undisclosed gender, date unknown).

Although student teachers believed puppets might be a distraction in class, Belohlawek et al. (2010) indicated that puppets can be successfully used to support learners to develop scientific concepts. In this regard, one student teacher believed that, although puppets might be a distraction in class, they might also support the learners to focus on the subject content. This student teacher indicated:

> So, this puppets [*sic*] won't distract just them (the learners) in a good way, but also help them interpret what is being taught, therefore they won't even realise that their being distracted in such a way they are actually focussing on what's important. (Student teacher, undisclosed gender, date unknown)

The CHAT diagram indicated the contradiction of control (McNeil 2013) between the two activity systems. Puppetry can be used to facilitate the border-crossing between a Western perspective on the curriculum and the oral traditions within IK. Some student teachers were unable to make this border-crossing, which indicates a tension between the two activity systems. These student teachers viewed the tenets of NOS in Life Sciences and Physical Sciences as more empirical in nature; '[i]t [using puppets] does not fit in with science', and 'it [using puppets] really does not concern the nature of science' (student teacher, undisclosed gender, date unknown). Another student teacher indicated, ‘you should physically conduct experiments’ (student teacher, undisclosed gender, date unknown). This finding is in line with the research of Adedoyin and Bello (2017), which indicated that student teachers have misconceptions on what the NOS entails. However, puppetry can encapsulate the metaphors that De Beer and Van Wyk refer to in Chapter 4 and, in so doing, address this contradiction of control.

Student teachers were mostly of the opinion that puppetry as a methodology is more suitable in the lower grades of schooling, ‘but I do not believe it will be as effective with high school students. Puppetry can be a very constructive teaching-and-learning method with younger learners’ (student teacher, undisclosed gender, date unknown). Some student teachers also experienced puppetry as an add-on and could not comprehend how puppets can be used in the classroom itself; ‘in Physical Sciences, there is a lot of work to do in a year and learners do sport (extramural activities), teachers cannot waste time on concerts’ (student teacher, undisclosed gender, date unknown). Another student commented, ‘I am against puppetry. Learners will choose drama as a subject if they want to do it’ (student teacher, undisclosed gender, date unknown).

Lastly, tensions were also identified in the role division of teachers under this theme. If puppetry is introduced as pedagogy, the teacher would have to incorporate creative and inventive elements within their methodology that might embarrass him or her; ‘I do not like puppetry, so even if it’s possibly a good way I will not feel comfortable as a teacher’ (student teacher, undisclosed gender, date unknown), and ‘to be laughed out by students and respect will be lost including self-respect’ (student teacher, undisclosed gender, date unknown). It is clear that student teachers struggled to accept the role of the teacher as an artist.

Although authors such as Keogh and Naylor (2008) and De Beer et al. (2018) indicated that puppetry as pedagogy has merits as a teaching methodology, it is evident from the discussions of the student teachers that they did not realise the importance of introducing a creative element into teaching to address the affective domain, as indicated by Lin (2014).

Student teachers were of the opinion that puppetry and storytelling is a time-intensive pedagogy

Tensions were evident between the rules and the object in the activity systems. Student teachers sensed that encompassing puppetry as teaching methodology might not fit the rigid time frames prescribed in the CAPS document. One student was of the opinion that, '[i]t could pose as an extremely time-consuming activity, thus other work could be neglected, or rushed'.

Student teachers realised that it would initially take more work from the teacher, which indicated a tension within the role division of a teacher. The teacher would have to move away from being only a facilitator of learning to that of the teacher as an artist:

> It takes a lot of hard work to actually be both the teacher and puppet at once as you have to not just focus on the classroom; you must focus on your puppet as well. It can be tricky sometimes as you as teacher don't want to lose focus of the children but in the same time try to entertain them. (Student teacher, undisclosed gender, date unknown)

It is interesting to note this teacher-centred perspective. It might be a far better approach to ask the learners to write a relevant puppet script for particular content and be the puppeteers themselves. Student teachers also realised that thorough research must be conducted before introducing puppetry into the curriculum, which focuses on the role of the teacher as curriculum interpreter:

> At high school level, careful selection must be made where the strategy (puppetry) is used, to work well. A proposal would be to use puppetry only at ethical/controversial topics. (Student teacher, undisclosed gender, date unknown)

Some student teachers highlighted puppetry and storytelling as creative pedagogies, addressing the affective domain

Some of the student teachers were more optimistic and were willing to make the epistemological border-crossing to implement puppetry as pedagogy in their future classrooms:

> Yes, because it was interesting and a new way to have class. I would like to implement this in my classroom one day. It was fun and different, and I think this could be a creative way to explain concepts. (Student teacher, undisclosed gender, date unknown)

A positive tension was evident between the two activity systems, as student teachers realised that puppetry could bring the fun element into teaching, which would provide a more meaningful teaching and learning experience:

> Puppetry brings a positive atmosphere in class because of fun being integrated. A positive attitude towards the subject is being developed which leads to a better participation of learners. (Student teacher, undisclosed gender, date unknown)

Here student teachers realised that puppetry as a 'tool' can enhance the achievement of the 'object'. Although some student teachers initially thought that puppetry as pedagogy is not suited for high school learners, they came up with solutions during their discussion using the De Bono's Hats strategy. They proposed that learners can use masks and do a role play instead of using puppets. Another solution was that learners at school level write their own scripts and produce their own puppet shows. This indicated a positive tension within the tools and object of the second activity system.

Student teachers believed that writing their own scripts could enhance creativity and critical thinking:

> When students write plays, foremost in many of their minds is [*sic*] how they will look, how they will sound, and how others will respond to them. Writing for the puppet allows them to be far more silly [*sic*], as well as take risks with accents, characters, and plots that they wouldn't try if they were required to act it out live. Not only does

> it help them learn the content as well as writing skills and dialogue formatting, but they also learn important lessons in collaboration, communication, critical thinking, and creativity. (Student teacher, undisclosed gender, date unknown)

Research indicated that there is a link between emotion and cognitive functions (refer to Ch. 4). This link could stimulate creativity (Immordino-Yang & Damasio 2007). After writing their own puppet scripts, making their own puppets and performing puppet shows, both Life Sciences students and Social Sciences students reported that they had enjoyed the activity. Examples of puppet shows from Life Sciences student teachers included a family visiting a botanical garden where they identified indigenous plants that have healing powers. Another group developed a script where an isiZulu-speaking lady and an Afrikaans-speaking lady exchanged remedies from their respective cultures for asthma. Examples of Social Sciences puppet shows included History curriculum themes. One group of student teachers used the history of the settlers coming to the Cape (De Villiers 2014) to develop their script. Their dialogue was between a new settler and a Khoi-san person. The settler wanted to clear a piece of land for his garden and the Khoi-san alerted the settler that he would end up destroying plants used for medicinal purposes by the Khoi-san. In another example, the script described the cultural differences between a settler and the Xhosa on the then eastern border between the Xhosa and settlers from the Cape.

Student teachers demonstrated the affordances of puppetry for the enhancement of self-directed learning

Self-directed learning was evident when student teachers completed the assignments on the puppet shows. Student teachers had to identify suitable topics in the CAPS document that were appropriate for the inclusion of IK and the use of puppets. They had to write their own scripts, thereby engaging with relevant learning material and developing their own learning resources (the puppets). This indicates a positive tension between

Source: Photograph taken by Josef de Beer, specific time and location unknown, published with permission from Josef de Beer.

FIGURE 9.2: In-service teachers learning about puppetry as pedagogy.

the two activity systems, as student teachers were able to use puppetry as pedagogy to facilitate the border-crossing between the Western curriculum and IK.

■ Conclusion

This research showed that there was a slight resistance from some student teachers to accept and engage with puppetry, as it was seen as inappropriate in higher grades. This speaks of 12 years of transmission-mode teaching and learning that they experienced as learners (Ramnarain & Schuster 2014) and resistance to change (Lukacs & Galluzzo 2014). Lukacs and Gallyzzo (2014) point out that, to implement change, teachers should have contextual expertise, should be able to solve problems and should take ownership for the change. Watt and Pascoe (2013) are of the opinion that Work-integrated Learning (WIL) is essential to prepare student teachers for their world of work. Although student teachers obtain experiences with different teaching strategies, such as puppetry, they sometimes use transmission-mode teaching, as indicated by Ramnarain and Schuster (2014), during their WIL period and therefore might not see the need to implement methodologies such as puppetry and storytelling in future in their classrooms. A positive stance was, however, taken by some students who saw the potential of introducing puppetry and storytelling into their classrooms through thorough planning, and they were quite willing to implement this teaching methodology during their WIL period and in their classrooms in future.

Although workshops are held on puppetry, which target (in-service) teachers as well, this work on puppetry should be expanded so that more teachers are aware of alternative modes. De Beer et al. (2018) have indicated that puppetry can be successfully implemented in the Biology (Life Sciences) classroom. Using puppetry and storytelling in the classroom could address the affective domain, which stimulates cognitive thinking and creativity (Immordino-Yang & Damasio 2007).

Summary

This research explored the perceptions of student teachers in Life Sciences, Physical Sciences and Social Sciences regarding the use of puppetry in a classroom to infuse IK into their respective curricula. As IK relies on an oral tradition and content is transferred by means of storytelling, puppets could be a vehicle in a classroom to convey knowledge through stories.

Literature indicates that stories can be an effective pedagogy in the classroom and that puppetry can be used successfully in an educational context. In this research, storytelling and puppetry were combined to infuse IK into the 'Westernised' curriculum, using an SDL approach.

The two guiding research questions were:

1. What are the perceptions of student teachers on the use of puppets within their teaching methodologies?
2. How can IK be infused into the curriculum through puppetry as pedagogy?

The research followed a basic qualitative design, and data were collected by means of questionnaires, reflective notes and analysis of class discussions where De Bono's Hats were used as the teaching methodology.

The findings reveal that some student teachers believed that puppetry might be an inappropriate pedagogy for older learners and should exclusively focus on primary school learners. Student teachers also indicated that puppetry and storytelling are time-intensive pedagogies but that it might be feasible through careful planning. Some student teachers highlighted the affordances of storytelling and puppetry as creative pedagogies and felt that it would address the affective domain in learning. Therefore, the findings indicated that some student teachers were unable, or found it difficult, to make the epistemological border-crossing between the methods employed in the Western curriculum and pedagogies such as puppetry, which are well aligned with IK.

Lastly, SDL was evident when the student teachers prepared their scripts and held their puppet shows. As they could identify their own learning needs, they had to engage in independent learning on the complexities of writing puppet scripts and were able to evaluate their own progress.

Chapter 10

The affordances of technology for teaching indigenous knowledge

Jako Olivier[a,b]
[a]UNESCO Chair Multimodal Learning and Open Educational Resources, Faculty of Education, North-West University, Potchefstroom, South Africa
[b]Research Unit Self-Directed Learning, Faculty of Education, North-West University, Potchefstroom, South Africa

Christo van der Westhuizen[a,b]
[a]School of Mathematics, Science and Technology Education, Faculty of Education, North-West University, Potchefstroom, South Africa
[b]Research Unit Self-Directed Learning, Faculty of Education, North-West University, Potchefstroom, South Africa

Dorothy Laubscher[a,b]
[a]School of Mathematics, Science and Technology Education, Faculty of Education, North-West University, Potchefstroom, South Africa
[b]Research Unit Self-Directed Learning, Faculty of Education, North-West University, Potchefstroom, South Africa

Roxanne Bailey[a,b]
[a]School of Mathematics, Science and Technology Education, Faculty of Education, North-West University, Potchefstroom, South Africa
[b]Research Unit Self-Directed Learning, Faculty of Education, North-West University, Potchefstroom, South Africa

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Introduction

This chapter deals with the intersections of technology and IK systems within the context of facilitating SDL. An overview is provided of relevant theoretical concepts of SDL, technology and IK systems as well as an interpretation of these issues in the South African CAPS at the school level. The empirical part of this chapter involves a critical literature review with a focus on operationalising aspects of learning and teaching in IK systems through technology. In conclusion, technological interventions for IK in teaching practice are suggested.

Theoretical framework

This chapter on the affordances of technology for teaching IK is rooted in literature on SDL. The theoretical framework for this research functions in a nexus with SDL as well as technology and IK. It is, nevertheless, important to consider that technology is not exclusively a Western concept, and Shizha (2016:47) notes that African IT was created from scientific knowledge from the continent which has had practical use. In this chapter, the focus is on the adoption of different learning technologies towards the teaching of IK. The subsequent sections enumerate the definitions and the relevant theoretical aspects from the prevalent discourses in terms of SDL, technology and IK systems.

Self-directed learning

The concept of SDL informs the way in which learning and the wider learning context is viewed in this chapter. Knowles (1975) defines SDL as:

> [*A*] process in which individuals take the initiative, with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies and evaluating learning outcomes. (p. 18)

Similarly, Gibbons (2002) defines SDL as:

> [*A*]ny increase in knowledge, skill, accomplishment, or personal development that an individual selects and brings about by his or her own efforts using any method in any circumstances at any time. (p. 2)

However, many and varied definitions exist for SDL (Bailey 2016:77; Leach 2000:10; Van Zyl 2016:28–29). This section covers what the concept of SDL involves, and how it is approached, operationalised and used in terms of technology.

The concept of SDL has been clearly delineated by Knowles (1975), Guglielmino (1978), Brockett and Hiemstra (1991), Candy (1991), Garrison (1997), Leach (2000), Merriam (2001), Gibbons (2002), Bolhuis (2003) and Nikitenko (2009), among others. In the South African context, there has also been several significant publications and postgraduate studies on SDL with regard to various strategies and disciplines (Bailey 2016; Bosch 2017; Breed 2016; Du Toit-Brits 2018; Mentz & Oosthuizen 2016; Tredoux 2012; Van Zyl 2016).

It is also imperative to consider the reason why SDL is relevant and how it can be approached. According to Merriam (2001:9), SDL denotes three goals, namely, 'development of the learner's capacity to be self-directed', 'the fostering of transformational learning' and 'the promotion of emancipatory learning and social action'. Different models of SDL have also been identified (Garrison 1997; Tredoux 2012:14–30; Van Zyl 2016:32–35). Bullock (2013:107) notes that SDL can be approached in terms of being a 'linear, stepwise process' or as being a more interactive process. From the literature, the link between SDL and self-regulated learning is evident, and in this research, self-regulated learning is regarded as being part of the overarching concept of SDL (cf. Tredoux 2012:10–11).

Self-directed learning should also be contextualised in terms of the specific circumstances in which learning occurs. In this regard, Bolhuis (2003:329–330) emphasises the importance of 'domain-specificness' and 'situatedness' of learning, and Bullock (2013:107) also refers to the importance of 'variety of factors, internal and external to the learner'. An increase in the use of technology in the wider educational context as well as contextualisation through the inclusion of IK systems is highly relevant. Furthermore, the potential of IK for SDL is clear from the explication by De Beer (2016:47–48).

Towards the operationalisation of SDL, Bolhuis (2003:343) suggests a ‘multidimensional approach to learning’ and a process-oriented teaching involving ‘helping students to gradually acquire the competences to regulate all components in learning’; ‘stimulating the knowledge-building process necessary to gain domain expertise’; ‘attention to emotional aspects of learning, including fostering motivation and a positive pattern of attribution, as well as helping students to enlarge their tolerance of uncertainty’; and that ‘schools and teachers need to treat the learning process and results as social phenomena’. The phenomenon of SDL can also be measured by means of instruments such as the Self-Directed Learning Readiness Scale (Guglielmino 1978) and the Self-Rating Scale of Self-Directed Learning (Williamson 2007), for example.

The benefits of digital technologies in supporting SDL are evident from literature (Bullock 2013:117; Du Toit & Pool 2016; Fleming, Artis & Hawes 2014; Kim et al. 2014; Nikitenko 2009; Tredoux 2012). In addition, the implications of SDL for machine learning have also been investigated (Gureckis & Markant 2012). Importantly, Du Toit and Pool (2016:214) even assert that ‘self-directed learning is a crucial competence for students in a blended-learning course’. Therefore, the symbiotic relationship between SDL and technology is evident.

Technology in learning and teaching

In this chapter, the concept of *technology* is understood as the use of computer- and Internet-based resources within a learning and teaching setting. This definition is opposite to a more general definition of technology, which could be more ‘multifaceted’ (Shizha 2016:49). The approach to technology in this chapter relates to Clark and Mayer’s (2016:7) definition of e-learning as 'instruction delivered on a digital device that is intended to support learning', and this learning context includes multimedia (Mayer 2017). Duval, Sharples and Sutherland (2017:1) emphasise the fact that digital technology, versus other technologies, tends to be more interactive. Crook and Sutherland (2017) acknowledge the influence of learning theories from behaviourism, cognitivism, constructivism and social constructivism. Technology in learning and teaching can support collaboration and personalisation. Furthermore, in order to approach technology within a wider context of IK systems, it is essential to consider the manner in which technology is integrated within the learning and teaching context as well as the effects of the digital divide on the usage of technology.

Technology allows for interaction, and therefore, it supports interdependence and collaboration. Moreover, Guglielmino and Guglielmino (2001:39) opine that learning should essentially occur in an interdependent rather than a dependent way. Similarly, Brewer (2016:37) also underscores the apparent interdependent nature of the SDL process. This aspect of learning technology links up with the traditional collaborative nature of knowledge generation within the African context. According to Shizha (2016:53), '[i]n pre-colonial Africa, the learning of skills in the production of knowledge and tools for socio-economic development was a community activity based on the concept of Ubuntu'. Therefore, the capabilities of learning technology should also be exploited in terms of facilitating technology-based Ubuntu, and what Shizha refers to as 'communality', with the aim of supporting SDL.

In addition, technology also supports personalisation of learning. Klašnja-Milićević et al. (2017) observe how '[s]emantic Web technologies, ontologies and adaptation rules can be used to improve the performance' of personalised systems. In this regard, Kim et al. (2014) also observed how a personalised system supports SDL. Du Toit and Pool (2016:236) remarked, regarding a blended learning environment and SDL, that 'blended courses should purposely include skills and elements required in SDL such as time management, reflection, communication and collaboration with peers – especially when it is students' first exposure to blended learning'. Therefore, self-direction needs to be considered throughout the design and implementation process when using any technology, whether it is in a blended or any other configuration.

However, it is important to note that, in terms of technology in a learning and teaching context, technology alone might not be sufficient to ensure effective learning. Colpaert (2014:20) notes that '[t]here is not enough evidence to suggest that technology, or any other type of educational artefact, carries an inherent, measurable and generalizable effect on learning' and that the effect emanates from a learning environment that was designed appropriately. In this regard, Picciano (2009:16) proposes a 'blending with purpose multimodal conceptual model for designing and developing blended learning courses and programs'. In this process, social, teaching, cognitive and learning presences must be considered (cf. Bosch & Pool 2019). Yet, all of this presupposes being able to have and use technology.

Access to technology cannot be assumed within the South African context and, as such, the so-called digital divide is prevalent. The concept of the *digital divide*, which refers to differences in access to the Internet, is ascribed to Lloyd Morrisett of the Markle Foundation (Hoffman, Novak & Schlosser 2000). In South Africa, the digital divide can be associated with historical economic differences in terms of racial backgrounds (Hoadley 2017; Nyahodza & Higgs 2017). Nonetheless, Nyahodza and Higgs (2017:46) remark that '[a]ccess to ICTs and information-related skills have been identified as key challenges in bridging the digital divide'. Bezuidenhout et al. (2017), however, note that having access to open data does not in itself bridge the digital divide and that individuals need to be empowered to use such resources. Despite their focus on open data, the implications of support in access to technology are also relevant for technology in general. In this regard, Bezuidenhout et al.

(2017:473) note that 'by focussing on resource provision instead of resource utilization, inadvertently perpetuate marginalization, exclusion and "data poverty"'.

Regarding IK, it is important to take note of the fact that e-learning can provide affordances in terms of contextualising learning, as e-learning allows for customisation of learning where 'tailoring content, instructional methods and navigation based on the needs of individual learners' can be achieved (Clark & Mayer 2016:15). In addition, the implications of augmented reality (Akçayır & Akçayır 2017) also need further research considerations in terms of virtually situating learning. Contextualisation is important as, like Shizha (2016:50) states, '[t]echnology has to be appropriate to the community that it serves' and must also attend to the needs of people. Conversely, Freire (2005:60) states that 'the oppressors are using science and technology as unquestionably powerful instruments for their purpose: the maintenance of the oppressive order through manipulation and repression'. Furthermore, Freire (2005) observes:

> The inhumanity of the oppressors and revolutionary humanism both make use of science. But science and technology at the service of the former are used to reduce the oppressed to the status of 'things'; at the service of the latter, they are used to promote humanization. (p. 133)

Hence, the use of technology has an important role to play towards supporting further recognition of IK systems.

Indigenous knowledge systems

The need for IK systems within a South African and a wider African context is relevant owing to historical selective recognition of specific knowledge systems. In this regard, Murove (2018:160) remarks that in the past, 'knowledge systems of the colonizing powers, imposed themselves on the colonised as the only legitimate knowledge to the exclusion of the knowledge systems of the colonised'. Furthermore, Shizha (2016:48) also observes that '[p]ost-colonial Africa suffered from the deskilling and disturbances in the course of development, heinously effected by colonial regimes'.

The colonial history of Africa led to a Eurocentric focus in education. Huaman and Brayboy (2017:3) note that 'education as the method of knowledge transfer (and validation) is rooted in Eurocentrism and accepted only as schooling, despite the myriad ways societies teach and learn'. However, they add that indigenous researchers have been challenging such definitions of knowledge with a colonial basis. Paulo Freire also questions who decides what knowledge is valid or not. Freire (2005:134) makes a statement in this context that 'the one who is doing the decreeing defines himself and the class to which he belongs as those who know or were born to, know; he thereby defines others as alien entities'.

As with the transformation agenda in higher education, an inclusion of IK systems could imply disruption. With regard to transformation, Waghid (2018:10) determined how educational technology can enhance such disruption and stated that the creation of 'pedagogical opportunities, through the use of educational technologies, may mitigate hierarchical teacher student interactions' where 'students have the equal ability to speak, to understand and to reshape an educational practice'. In addition, the role of indigenous languages together with IK is emphasised by Shava and Manyike (2018).

Mkhize et al. (2016:1) state that 'African IK systems take as their point of departure the experiential and epistemological frameworks of the peoples of the African continent, and those of African descent globally'. However, they also note that this IK system 'is part of international or world knowledge, the exception being that it has been underdeveloped or marginalized, as a result of colonialism' (Mkhize et al. 2016:1). Furthermore, Shava and Manyike (2018:36) state that the 'accumulated knowledge that indigenous people generate is embedded in their culture and embodied in their practices' and is transmitted orally.

Within the context of South African classrooms, there has been a move to accommodate IK systems within Life Sciences (De Beer 2016; De Beer & Van Wyk 2012; De Beer & Whitlock 2009); Physics (Sithole 2016); Natural Sciences, Physical Sciences and Mathematics (De Beer 2016); primary school science (Adyanga & Romm 2016); History (Mvenene 2017); and science and medical teaching (Hewson 2014), among others. Through such research, there has been a move towards what Murove (2018:174, 175) calls 'advocacy for an authentic knowledge that is rooted in context' and attempts towards 'the intellectualisation and production of local knowledges'.

Murove (2018:162) argues that 'the indigenisation of knowledge through the pursuit of IK systems intellectualisation and knowledge production implies that authentic knowledge should be culturally contextual'. Furthermore, IK should be considered within specific places (Adyanga & Romm 2016:11) and be regarded as open, transforming and dynamic systems (Shava & Manyike 2018:37). Correspondingly, De Beer (2016:44) makes a case for 'the inclusion of indigenous knowledge through an embodied, situated and distributed cognition lens, rather than from a political perspective' within existing school subjects.

An empirical investigation into the aforementioned aspects was conducted by means of a critical literature review.

Technology, indigenous knowledge and self-directed learning grounded in the policy documents

With regard to the grounding of IK and SDL in the South African context, the two policy documents consulted were CAPS and the Professional Development Framework for Digital Learning (PDFDL).

The South African Curriculum and Assessment Policy Statement

When discussing the integration of IK, SDL and technologies into teaching and learning for teacher training institutions, in-service teachers and pre-service teachers, the National Curriculum Statement (CAPS) Grades R-12 always serves as the point of departure.

One of the main principles of CAPS Grades R-12 is valuing IK systems; 'acknowledging the rich history and heritage of South Africa as important contributors to nurturing the values contained in the Constitution' (Republic of South Africa 2011a:5). Furthermore, as part of the general aims cutting across all subjects in the school curriculum, CAPS provides and encourages knowledge and skills pertaining to SDL, IK and technology integration. Thus, the five general aims include sufficient focus towards SDL, IK, technology integration, contexts and issues, and the first aim specifically proposes that (Republic of South Africa 2011a):

> [*C*]hildren acquire and apply knowledge and skills in ways that are meaningful to their own lives. In this regard, the curriculum promotes knowledge in local contexts, while being sensitive to global imperatives. (p. 5)

It is especially with this aim that educators should seek opportunities within the class context to integrate IK.

In addition, the second aim specifically obliges to (Republic of South Africa 2011a):

> [*E*]quipping learners, irrespective of their socio-economic background, race, gender, physical ability or intellectual ability, with the knowledge, skills and values necessary for self-fulfilment, and meaningful participation in society as citizens of a free country. (p. 4)

And more so encouraging lifelong learning principles by 'facilitating the transition of learners from education institutions to the workplace' (Republic of South Africa 2011a:4).

It is also important to note that CAPS is based on the following principles that are relevant to IK, SDL and technology integration, among others (Republic of South Africa 2011a):

- social transformation, whereby ensuring that the educational imbalances of the past are redressed and that equal educational opportunities are provided for all sections of the population
- active and critical learning by encouraging an active and critical approach to learning with high knowledge and high skills to be achieved at each grade setting, high, achievable standards in all subjects, also showing progression in content and context
- a strong focus on human rights, inclusivity, environmental and social justice by infusing the principles and practices of social and environmental justice
- valuing IK systems by acknowledging the rich history and heritage of this country as important contributors to nurturing the values contained in the Constitution. (p. 4)

This highlights the fact that social transformation, inclusivity and environmental justice are essential for the integration and valuing of IK in multicultural school contexts and that active and critical learning is fundamental to the fostering of SDL skills. But the most important value of the CAPS, regarding the combination of SDL, IK and technology integration, is that it aims to create learners who are capable to (Republic of South Africa 2011a):

> [*I*]dentify and solve problems and make decisions using critical and creative thinking, work effectively as individuals and with others as members of a team; organise and manage themselves and their activities responsibly and effectively; collect, analyse, organise and critically evaluate information; communicate effectively using visual, symbolic and/or language skills in various modes; *use science and technology effectively and critically showing responsibility towards the environment and the health of others;* and demonstrate an understanding of the world as a set of related systems by recognising that problem-solving contexts do not exist in isolation. (pp. 4–5; [*emphasis in original*])

Lastly, the fifth general aim asks that (Republic of South Africa 2011a):

> [/]nclusivity should become a central part of the organisation, planning and teaching at each school and can only happen if all teachers have a sound understanding of how to recognise and address barriers to learning, and how to plan for diversity, especially asking for proper training of pre-service teachers. (p. 4)

This is generally the reason why IK, SDL and technology integration are omitted from teaching and learning activities.

In summary, CAPS provides ample opportunity and practices that are essential to empower communities and better equip learners with critical skills to become self-directed learners, have a fundamental understanding of IK and how to skilfully integrate technology to achieve these goals. Educators must adhere to the call of the general aims of CAPS (Republic of South Africa 2011a).

The Professional Development Framework for Digital Learning

The importance of the DBE's proposed PDFDL also needs to be discussed. It is good news that the DBE will roll out PDFDL from 2019, wherein they aim to build educators' competencies in facilitating learning with digital tools and resources (DBE 2017). Goal 16 of the DBE Action Plan to 2019 commits the Department and relative role players to improve the professionalism, teaching skills, subject knowledge and computer literacy of teachers throughout their careers. Furthermore, the Integrated Strategic Planning Framework for Teacher Education and Development commits to the investment in digital technologies to support the enrolment of the strategy with regard to (DBE 2017):

- the need for specific teacher knowledge and practice standards for each subject area or area of teacher expertise
- the establishment of Professional Learning Communities to strengthen teacher professionalism. (p. 8)

The PDFDL will guide the professional development of teachers and all stakeholders using digital tools and content resources to support improved learning outcomes and higher learner achievement in the curriculum. It also provides guidelines for professional development, specifically in order to, firstly, provide capable teachers and lecturers who can successfully integrate technologies to improve teaching and learning. Secondly, to afford leaders, managers and support personnel who are capable of facilitating and continuously guiding the advance of teachers' digital learning capabilities. Therefore, the main target employees of this framework will be those who train teachers, school leaders and managers as well as the teachers themselves, e-learning experts and curriculum subject professionals (DBE 2017).

It is important to note that this framework will encourage educators to do clear planning for the integration of digital learning, so that learners can achieve curriculum goals with the support of appropriate teaching and learning approaches where digital tools and content resources are used. This framework will show that adopting a range of pedagogical approaches, such as SDL, problem-based and project-based learning, will improve the potential of limited digital tools and resources to support and enhance learning (DBE 2017). The framework will be successful if teachers are able to gain a clear understanding of how digital applications, resources and tools will be used to meet particular goals within subjects of the curriculum to increase learners' performance (Moseley et al. 1999).

Digital learning involves the use of appropriate digital tools and resources in both e-learning and mobile learning to reinforce teachers' teaching and learners' learning experiences, resulting in better learner performance and enhanced achievement of curriculum learning objectives. The White Paper on e-Education (2004) required a changing teaching and learning methodology and is still upheld by the new proposed digital framework where teachers and learners will have access to (DBE 2017):

- high-quality, relevant and diverse resources, beyond what current school libraries are providing
- means of communicating and collaborating with other learners and teachers
- opportunities of creating and presenting new knowledge. (p. 11)

This requires a transition in learning that fully harnesses the power of digital tools and resources to impact all aspects of learning, including how teachers mediate learning, how learners use digital tools and content resources, and how that learning is assessed (DBE 2017). The aims of CAPS, as was stated earlier in this chapter, are to produce learners who can do just that. These aims align with the pedagogical factors of the change presented in this framework to develop learning activities that could embrace a wide variety of opportunities to use digital tools and resources.

The next section presents the empirical investigation by means of a critical review of existing literature on technologies that support the affordances of IK.

Technologies that support the affordances of indigenous knowledge: Indications from current literature

Although the two terms may seem paradoxical, technology and IK may be infused in an effective way. As was noted earlier in the chapter, we define technology as computer- and Internet-based resources that can be used in an educational setting. We thus accept the definition by Siyanbola et al. (2012) but relate it specifically to computer and Internet technologies. Siyanbola et al. (2012) define technology as the application of knowledge in providing solutions to problems. That being said, it is accepted that not all technologies are deemed appropriate when attempting to teach IK in an SDL context. It is clear that one first needs to unpack appropriate technologies and ITs (as it provides the right framework for recommending technologies in IK to enhance an SDL context).

Defining appropriate technologies and indigenous technologies for indigenous knowledge

Appropriate technologies

Various definitions exist regarding appropriate technologies and what they encompass. One of the earliest definitions found in the body of scholarship is that of Thormann (1979) where appropriate technologies is defined in terms of resources, small production units and people. When defining appropriate technologies in terms of resources, he states that they should be rigorous in terms of labour and using products that are produced domestically, and cost-effective in terms of capital and the selection of suitably trained personnel. He continues to note that the production units should be effective despite being modest; replicable; and easy to function, sustain and repair. They should also be inexpensive and readily available to all. Finally, Thormann refers to appropriate technology in terms of the people who use it and hence states that it should be compatible with local cultural and social environments. Iloka (2016:3) notes that appropriate technology can be divided into hard and soft technologies; hard technologies use ideas from Natural Science to manage issues related to humans, whereas soft technologies use local laws and experiences to promote human development. Recently, Tharakan (2015) defined appropriate technologies as technologies where production requires little capital, uses local materials, is labour-intensive, and is small-scale and affordable. More importantly, Sianipar et al. (2013) suggest that appropriate technologies should be used to sustain any efforts in communities. This links directly to IK interventions posed in communities. According to Sianipar et al., technologies are viewed as appropriate when the user of such technologies can afford them, while, at the same time, having technology that is sophisticated enough to function in a high technical system that can increase the user's wealth and skills. In view of this, it becomes evident that IK and appropriate technologies, with their unique characteristics, have a common ground.

Characteristics of appropriate technologies for indigenous knowledge

There are varied opinions about the characteristics of appropriate technologies for IK; however, the feature that does appear to be dominant is that appropriate technology encompasses the holistic inclusion of the local community throughout the development process (Tharakan 2015). These include that they should be cost-effective and require minimal capital outlay, should make use of local material as far as possible, should be fairly labour-intensive, small-scale and affordable (Iloka 2016; Tharakan 2015). The philosophy of appropriate technologies demands that they be grounded within the community and that the implementation and development thereof can engage the community, which should result in capacity-building and empowerment (Tharakan 2015). This implies that, within the community, appropriate technologies should be comprehensible, controllable and maintainable. In order for the more sophisticated technology to be successfully operated and maintained, the local community needs to keep up to date with technical aspects. This is often not possible within local communities (Tharakan 2015). Local communities should always be included in all stages of any form of technological implementation or intervention, including the conceptualisation thereof; the process of development, from innovation to development to implementation; as well as the monitoring and evaluation of the intervention (Tharakan 2015). Appropriate technologies should minimise or, if possible, eliminate adverse environmental impacts and at the same time be adaptable and flexible (Tharakan 2015). Technologies that are capital-intensive and that are of a large scale can still be deemed appropriate provided that the emphasis is on empowering the community, limiting environmental impacts and increasing sustainability (Tharakan 2015).

Indigenous technologies

Indigenous technologies are defined differently by different researchers. Gumbo (2012) defines indigenous as something that is inborn in a specific context. He continues by saying that ITs are those artefacts that indigenous people produce. Manabete and Umar (2014:54) define technology as the manner in which resources, skills and knowledge are applied to address the objectives and requirements of a specific group of people. However, they (Manabete & Umar 2014:56) note six characteristics that set aside ITs from other technologies:

- ITs are practical, receptive and accountable within the ecology where they originate
- they promote a culture of learning that assists in the revival and transformation of knowledge
- by using meaningful interaction, they aim to incorporate knowledge and experiences of the original world from where they come from
- they exist and function on an ethical level
- they are in agreement with the natural order of things
- they have fundamental value because their history and origin is known.

Both appropriate technologies and ITs are relevant in the quest to understand the use of technology in the affordances of IK in education. The following section specifically gives examples of technologies.

Examples of technologies

Different technologies can be used to promote the teaching of IK. As mentioned above, Iloka (2016) refers to soft and hard technologies. Soft technologies refer to the way in which indigenous methods are applied to solve communal problems.

This entails the use of indigenous laws as well as experiences to change nature and encourage the advancement of society (Iloka 2016:3). Hard technology refers to the application of knowledge derived from Natural Science, thereby converting the ideas from soft technology into something more tangible.

In the literature study by Gumbo (2012), reference is made to various fields that employ ITs. These include:

- food technologies (e.g. dehydrated granular food products)
- metallurgical technologies (e.g. carbon steel, which was produced in Tanzania approximately 2000 years ago, and copper smelting, which was developed in West Africa)
- astronomical technologies (e.g. a stone astronomical observatory was created in Kenya)
- tools technologies (e.g. bone tools and blades from Southern and Eastern Africa)
- architectural and engineering technologies (e.g. the construction of Great Zimbabwe, the stone city, more than 800 centuries ago)
- transport technologies (e.g. the construction of watercrafts for jungle canoes)
- agricultural technologies (e.g. the cultivation and harvesting of barley, cowpea, millet and sorghum)
- medical technologies (e.g. aspirin and the use of herbs for various medical conditions)
- communication technologies (e.g. drumming scripts that were used to relay news over great distances).

Where the above-mentioned examples refer to ITs, Toth, Smith and Giroux (2018) give examples of computer- and Internet-based resources to empower indigenous people. Their article addresses problems that indigenous people encounter with regard to basic services such as technology, education and health care. As far as technology is concerned, they refer specifically to public spaces equipped with computers and free access to the Internet. This should preferably be in a community meeting place, which strengthens the indigenous culture of unified learning, meeting with elders and children's centres. Concerning education, they suggest that computer technology can significantly improve the lives of indigenous people. Improved access to communications technology and computers in schools and communities will promote distance learning, which enables residents to remain in their communities while undergoing necessary training. Access to instruction in technology and programming can assist in reinforcing and distributing their culture by creating their own online content. Using open-source software is also important for creating their own online content. Access to technology in education can also assist in incorporating indigenous languages into the classroom and serve as a way to preserve and protect orally transferred knowledge from economic exploitation through adequate licencing.

Furthermore, various technologies can be used to provide access to health care (Toth et al. 2018). These include remote patient monitoring and teleconferencing with specialists, two-way video feeds and video conferencing that assist midwives in remote locations to access the advice of doctors, iPads or tablets that assist hospitalised patients to keep in touch with their families who live in remote areas (this is done through Skype, FaceTime and other face-to-face communication applications), online support groups and video conferencing that assist in supporting the community with issues such as substance abuse and suicide. A critical literature review was executed to the use of technology in IK.

Critical literature review

In order to perform the critical review of the existing literature, a detailed search was carried out using a combination of search terms that were determined by the framework of this chapter. The selection criteria for inclusion of the documents were as follows:

- documents published between 2008 and 2018
- documents sourced using the following search terms: ‘indigenous knowledge’, ‘appropriate technology’, ‘indigenous technology’ and ‘indigenous education’

- documents published in peer-reviewed journals or conference proceedings which are accessible via the EBSCOhost database
- quantitative, qualitative or mixed-method research
- research from any content area.

The initial search provided 64 documents for investigation. Upon initial perusal of the abstracts, only 10 documents were retained. The full texts were studied and key works in the field, which were not identified through the search, were included for analysis. This yielded a total of 12 documents for analysis, which are discussed in Table 10.1.

From Table 10.1, it is evident that the research on IK, and especially technology in IK, has a broad scope. The documents from the search were categorised into six specific aspects. Although not all documents made a mention of each of the aspects, the results from each aspect are discussed.

Indigenous knowledge

From the documents consulted, it is clear that IK is seen as an important concept and has been receiving special attention since the dawn of democracy in South Africa. Although IK has been prioritised, the implementation and infusion thereof into the school and higher education curriculum have not yet materialised. Specific subjects where IK can easily be infused have been identified:

- Life Sciences
- Natural Sciences
- Mathematics
- Technology Education.

All four of these subjects have successfully been used to incorporate IK into the curriculum.

TABLE 10.1: Summary of documents for the critical literature review.

Source	IK	Appropriate technology or IT	Addressing the characteristics of appropriate technologies for IK	Context	Example of technology	Education and teaching
De Villiers, L., De Beer, J. & Golightly, A., 2018, 'Developing design principles for an IK intervention for Life sciences teachers based on socio-constructivist pedagogical strategies', *ISTE* 2018. pp. 165–172.	Paper notes that educational policies focus on IK, but the Department of Education failed to train teachers to include IK in their teaching. The paper further focuses on developing design principles to be used in IK interventions for Life sciences teachers.	None	Emphasises the importance of including the community.	Life sciences teachers attending an IK intervention (75 teachers).	None	The intervention (short course) was too short. Furthermore, nine design principles were identified. These included an emphasis on involving holders of IK in the teacher training. Several factors influence teachers' inclusion of IK in their teaching.

Table 10.1 continues on the next page →

TABLE 10.1 (Continues...): Summary of documents for the critical literature review.

Source	**IK**	**Appropriate technology or IT**	**Addressing the characteristics of appropriate technologies for IK**	**Context**	**Example of technology**	**Education and teaching**
Speight Vaughn, M. & de Beer, J., 2018, 'Contextualising science and mathematics teacher professional development in rural areas', *ISTE* 2018, pp. 289–297.	The paper reflects on how teacher professional development should be contextualised (with a specific focus on IK). It was found that IK is bound to home communities and not given enough attention in school.	Paper mentions 'boomwhackers' to represent indigenous inspired music (used to teach fractions in Mathematics).	None.	The research is placed in the Hantam region in the Northern Cape, which contains specific flora, fauna, IK and culture. Seventy-seven teachers attended an intervention, which included the application of IK in their classrooms.	Boomwhackers	Teachers are given the opportunity to engage with the community (albeit indirectly) during the professional development intervention. This in turn informed teachers' competencies to contextualise their Science and Mathematics teaching.

Table 10.1 continues on the next page →

TABLE 10.1 (Continues...): Summary of documents for the critical literature review.

Source	IK	Appropriate technology or IT	Addressing the characteristics of appropriate technologies for IK	Context	Example of technology	Education and teaching
Seleke, B., Speight Vaughn, M. & De Beer, J., 2018, 'Senior phase technology teachers' professional development and implementation needs: A case study', *ISTE* 2018, pp. 402–411.	Paper highlights the need to infuse IK into technology education. It continues to report on the challenges experienced by teachers when attempting to infuse IK into their classes.	None	None	Study is placed within the Namakwa district. Eight senior phase technology teachers participated in professional development.	None	Teachers in the study confirmed that they have a need for professional development in order to effectively infuse IK into their classes.

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TABLE 10.1 (Continues…): Summary of documents for the critical literature review.

Source	IK	Appropriate technology or IT	Addressing the characteristics of appropriate technologies for IK	Context	Example of technology	Education and teaching
Sianipar, C.P.M., Yudoko, G., Adhiutama, A. & Dowaki, K., 2013, 'Community empowerment through appropriate technology: sustaining the sustainable development', *Procedia Environmental Sciences*, 17(2013),1007–1016.	None	Study set out, among others, to determine what technology can be applied to solve community problems. Defines appropriate technology as various social and cultural efforts in the design of a product.	Although a strong focus on appropriate technology, no focus on IK is given.	Study used a literature review but specifically focussed on rural communities.	None	None

Table 10.1 continues on the next page →

TABLE 10.1 (Continues...): Summary of documents for the critical literature review.

Source	IK	Appropriate technology or IT	Addressing the characteristics of appropriate technologies for IK	Context	Example of technology	Education and teaching
Gumbo, M.T., 2012, 'Claiming indigeneity through the school curriculum, with specific reference to technology education', *Africa Education Review*, 9(3), 434–451.	Study focussed on determining (through a literature review) the extent to which the technology education curriculum (of South Africa) accommodates IK.	A specific focus is placed on the integration of ITs as part of IK systems.	None.	Technology education in South Africa.	Examples of indigenous technologies: food technologies; metallurgical technologies; astronomical technologies; tools technologies; architecture and engineering technologies; transport technologies; agricultural technologies; medical technologies; and communication technologies.	Paper makes a case for including the mentioned examples of indigenous technologies in the technology education curriculum.

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TABLE 10.1 (Continues...): Summary of documents for the critical literature review.

Source	IK	Appropriate technology or IT	Addressing the characteristics of appropriate technologies for IK	Context	Example of technology	Education and teaching
Jackson, De Beer & White, 2016, Teachers' affective development during an indigenous knowledge professional teacher intervention.	The paper presents the way in which Natural Sciences and Life Sciences teachers develop in the affective domain, resulting from exposure to an IK professional development course. It indicates teachers' attitudes, values and beliefs on IK.	None	None	High school teachers (Natural Sciences and Life Sciences) from the North-West province who agreed to participate in an IK intervention as part of their professional development.	None	The intervention gave teachers a better understanding and appreciation of IK and made them more reflective practitioners. Teachers said that teaching IK could inspire interest and motivation in learners in the field of Natural Sciences and Life Sciences.

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TABLE 10.1 (Continues...): Summary of documents for the critical literature review.

Source	IK	Appropriate technology or IT	Addressing the characteristics of appropriate technologies for IK	Context	Example of technology	Education and teaching
Lukhele-Olorunju & Gwandure, 2018, Women and Indigenous knowledge systems in rural subsistence farming: The case of climate change in Africa	The paper focuses on how women in rural African communities use IK systems to assist with their subsistence farming. These IK systems help farmers to mitigate and survive the negative effects of changing climates.	Indigenous technologies are used to treat livestock and poultry. It is also used to mitigate the effects of climate change on crop, livestock and poultry production.	This paper addresses the majority of the characteristics of appropriate technologies for IK.	The paper explores women who are involved in rural subsistence farming in Africa.	Smoke technology, which includes smoke-water which improves seed germination, seedling growth and crop production as well as clay pots which are sealed with cow dung, which are used to store grain.	None
Nelson, 2012, 'You don't have to be black skinned to be black': Indigenous young people's bodily practices	Not discussed in detail, but the author does link the concept of 'indigenous bodies' to IK and cultural practices.	The article refers to 'normalising technologies', which does not fit into the scope of this paper.	None	Fourteen participants in Australia were interviewed several times over a period of two and a half years.	None	The paper makes specific reference to physical education and focuses on health and education issues.

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TABLE 10.1 (Continues...): Summary of documents for the critical literature review.

Source	IK	Appropriate technology or IT	Addressing the characteristics of appropriate technologies for IK	Context	Example of technology	Education and teaching
Patel, Maley & Mehta, 2014, Appropriate technologies in the globalised world: FAQs	The focus of the paper is on appropriate technologies and explores the link between technology and indigenous as well as Western settings.	The paper focuses on appropriate technologies. It suggests that excessive deviation from indigenous viewpoints can result in unsuccessful projects in appropriate technology.	The paper explores several questions that relate directly to the characteristics of appropriate technology as described above.	This is more of an opinion piece and not the report of an empirical work.	They mention of technologies (especially in the farming and agricultural arena), such as Husk Power Systems, which convert rice husk into electrical power, and treadle pumps, which help farmers to increase their cultivable land. They also mention eco-friendly technologies.	The paper does not specifically refer to teacher education, but it does refer to the link between appropriate technologies and education (formal and informal).

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TABLE 10.1 (Continues...): Summary of documents for the critical literature review.

Source	IK	Appropriate technology or IT	Addressing the characteristics of appropriate technologies for IK	Context	Example of technology	Education and teaching
Brits, De Beer & Mabotja, 2016, Through the eyes of a puppet: a pedagogy of play for the Incorporation of IK in the life- and Natural Sciences curriculum	The paper provides guidelines for teachers and prospective teachers as to how storytelling and puppets can be used in Life Sciences and Natural Sciences classrooms.	Puppets are used as a form of technology.	Although not pertinently mentioned, the majority of the characteristics of appropriate technology are addressed.	Primary and secondary school teachers in Limpopo and North-West province attended a short course on the incorporation of IK into the CAPS curriculum. Thereafter, 12 teachers took part in the puppetry research, which included focus group discussions.	Puppets	The short course highlighted how IK can be infused into the CAPS curriculum. Findings showed that in the field of Natural Sciences and Life Sciences, teachers do not use the pedagogy of puppetry; they lack the required training, skill and knowledge of pedagogy and content to use the pedagogy of puppetry as a pedagogy; they were able to see the value of drama and puppetry as a pedagogy; and the border-crossing between science and IK can prompt their SDL..

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TABLE 10.1 (Continues...): Summary of documents for the critical literature review.

Source	IK	Appropriate technology or IT	Addressing the characteristics of appropriate technologies for IK	Context	Example of technology	Education and teaching
Jacobs, De Beer & Petersen, 2016, The professional development of teachers in terms of their understanding, experience and application of indigenous knowledge and cooperative learning	Life Sciences teachers were presented with a professional development, which was concerned with the use of IK and CL in the curriculum.	No specific mention is made of technology.	None	Life Sciences teachers from North-West province and Limpopo who attended a teacher professional development programme.	None	Many teachers confuse CL with group work and have difficulty implementing CL in the classroom owing to their limited knowledge of pedagogy and content.

Table 10.1 continues on the next page →

TABLE 10.1 (Continues...): Summary of documents for the critical literature review.

Source	IK	Appropriate technology or IT	Addressing the characteristics of appropriate technologies for IK	Context	Example of technology	Education and teaching
Toth, Smith & Giroux, 2018, Indigenous peoples and empowerment via technology	Not concerned with IK but rather indigenous people and the use of technology.	The article explores the effect of increased access to communications technology in the lives of indigenous people in Quebec.	Inclusion of the local community is emphasised, can be cost-effective as opposed to transportation costs.	Indigenous people of Quebec.	Internet access instruction in technology and programming; technology that allows for remote patient monitoring; two-way video feeds to assist midwives in remote locations; medical video conferencing, iPads or tablets together with Skype, FaceTime and other face-to-face communication applications to allow hospitalised individuals to keep in touch with family members.	Access to technology can assist in various ways: providing access to distance learning; incorporating indigenous languages in the classroom; it can empower indigenous people to reinforce and disseminate their culture through the creation of their own online content. Various health care issues can also be addressed through technology.

IK, indigenous knowledge; IT, indigenous technologies; CL, cooperative learning.

Appropriate technology or indigenous technology

From the documents referred to, it became clear that more of the literature in our search results focussed on appropriate technologies as opposed to ITs. Some documents did, however, make a mention of examples of ITs (see 'Examples of technologies' for examples of technologies). It is important to note the fact that several studies showed how IK perspectives need to be prioritised when using appropriate technologies. The link between appropriate technologies and IK was also highlighted owing to both placing great focus on the community in which they are implemented.

Addressing the characteristics of appropriate technologies for indigenous knowledge

As mentioned above, several specific characteristics of appropriate technologies need to be evident. From the corpus of documents referred to in this literature study, it became evident that the most prominent characteristic is the engagement of the community. All the documents that were focussed on appropriate technology highlighted the inclusion of the community. Two documents, however, specifically focussed on addressing all the characteristics of appropriate technologies. None of the documents, however, gave specific insight into appropriate technologies and how their characteristics can inform the affordances of IK.

Context

Most documents were placed within the context of South African education. Specifically, the documents focussed on Life Sciences, Natural Sciences, Mathematics and Technology education. Although not all of the documents were placed in a specific context (being literature review studies), the documents that made a mention of their specific contexts were mostly placed within rural communities (e.g. Hantam, Namakwa and Limpopo). The two documents that were not placed in the South African context made a mention of Australia and Quebec. It is thus difficult to derive any specific conclusions about the context.

Example of technology

Six of the documents made no reference to technology at all. The rest could all be classified into two main categories relating to examples of technology, namely, examples of ITs and computer and Internet-based technologies. Indigenous technologies include food technology, metallurgical technology, astronomical technology, tools technology, architecture and engineering technology, transport technology, agricultural technology, medical technology, communications technology and educational technology in the form of 'boomwhackers' and puppets. Although not evident in the search results, it is also worth mentioning Jackson, De Beer and White's (2016) use of Foldscope technology to promote IK. The examples that were listed for computer and Internet-based technologies include Internet access, communications technology such as two-way video feeds and video conferencing, and mobile technology in the form of iPads and tablets.

Education and teaching

The aspect of education and teaching can be classified into three different categories, namely, teacher training, education outside of teacher education and, the largest component, teaching in practice.

With regard to teacher training, the documents revealed that emphasis should be placed on involving the holders of IK in teacher training to provide authentic learning experiences for prospective teachers. Two articles dealt with education outside the field of teacher education: the first article focuses specifically on physical education with specific focus on health and education issues; the second article offers suggestions on how to link appropriate technology with education.

The largest component of information from the corpus of documents, which relates to education and teaching, makes reference to teaching in practice. Various factors influence teachers' inclusion of IK in their teaching. Teachers who were given the opportunity to engage with the community in IK informed their competencies to contextualise their Science and Mathematics teaching. Not only did the teachers express the need for professional development in the field of IK and how to infuse IK into their classrooms, but they believed that teaching IK could promote learners' interest and motivation in the sciences. Six of the documents involved an intervention programme to inform teachers about how to include IK in their classrooms. The research on these intervention programmes were able to identify design principles for the design of future courses and programmes, give teachers a better understanding and appreciation of IK, make the teachers more reflective practitioners and highlight how IK can be infused into the CAPS curriculum.

Further to the professional development regarding IK, various other teaching–learning aspects were revealed in the corpus. Teachers do not generally use the pedagogy of puppetry in Natural Sciences and Life Sciences (refer to Ch. 8). In addition, although teachers can see the affordances of drama and puppetry as a pedagogy, they lack either the necessary training and skills or PCK to use puppets effectively in the classroom. Teachers' often underdeveloped views of the tenets of science (which includes its creative nature) also lead to the marginalisation of puppetry as a pedagogy. Teachers generally confuse the concept of CL with group work. As with puppetry, teachers also have limited PCK to effectively implement CL in the classroom. Within a broader educational arena, one of the articles pointed out that access to technology can provide indigenous people with the opportunity to study through distance education, which holds several advantages for rural communities, namely, it can assist in incorporating indigenous languages in the classroom, and various health care issues can be addressed.

The next section deals with the wider potential of Geographical Information Systems (GIS), Google Earth and Maps to integrate IK, SDL and technology in the curriculum as an example of how the combination of these elements can be operationalised.

The potential of Geographical Information Systems, Google Earth and Maps to integrate indigenous knowledge, self-directed learning and technology in the curriculum

Geographical information systems, Google Earth and Maps can be integrated into subjects across the curriculum, but they are most fitting for the CAPS of Geography. The CAPS document for Geography insists that SDL skills are nurtured through relevant teaching and learning strategies. The fourth general aim is very specific as it aims (DBE 2017):

> [*T*]o produce learners that are able to identify and solve problems, as well as make decisions by using critical and creative thinking, and by working effectively as individuals and with others as members of a team; use science and technology effectively and critically, by showing responsibility towards the environment and the health of others; and demonstrate an understanding of the world as a set of related systems by recognising that problem-solving contexts do not exist in isolation. (pp. 4, 5)

Learners are also encouraged to nurture an obligation towards sustainable development, a consciousness of sensitive issues and great inequality in the world, as well as thorough balanced evaluations of social and environmental issues (Van der

Westhuizen & Golightly 2018). Learner-centred instructional methods are designed to foster Geography learners' skills such as information management skills, critical thinking, problem-solving, self-assessment, collaborative and CL – all typical skills of self-directedness (Golightly & Van der Westhuizen 2017).

As was stated earlier, a general aim of Geography in the South African CAPS is to encourage the use of applicable technology applications and GIS. It suggests that GIS can develop skills in learners that help them understand and solve global challenges. 'The catalytic ability of GIS to grasp both the world in general and the complexity of geographic phenomena in particular' (Madsen & Rump 2012:98) has revitalised the importance of and interest in school Geography. Indeed, the swiftness with which GIS can dynamically re-represent the globe allows to address current critical issues, for example, biodiversity, limited water resources, agriculture, economics and sustainability (all applicable to IK as well). According to Madsen and Rump (2012), the leading claim for including GIS practice in Geography is to develop learner's geospatial thinking skills, which at the same time improve learners' conceptual understanding and exploring capabilities with specific exercises on how to solve real-world problems. In fact, when teaching Geography themes *through* GIS, it is advised that fostering self-directed teaching and learning strategies such as PBL be integrated to establish and enhance these skills. Geographical Information Systems education also cultivates the expansion of higher-order thinking skills, such as problem-solving, critical thinking and reflection. Thus, the CAPS, especially for Geography, poses good potential in adhering to the mentioned advantages of GIS integration (Van der Westhuizen & Golightly 2018).

Regarding IK in the Geography classroom, teachers should embrace different IK systems from the diverse group of learners in class and they should harness the technological knowledge of learners (Bornman 2018). With reference to IK in the CAPS, the general aims for Geography hold as one of its principles that it 'values indigenous knowledge systems and should acknowledge the rich history and heritage of this country as important contributors to nurturing the values contained in the Constitution' (Republic of South Africa 2011c:5). This is also supported in the DBE document 'Responding to diversity' (Republic of South Africa 2011b), which points out the issue of diversity at different levels of society and stresses that learners hold different life experiences coming from a variety of communities. This document further outlines strategies to enhance inclusive teaching such as the fact that technology must be implemented and integrated in the teaching and learning processes to ensure that IK is valued and instilled into school activities. By infusing IK into the Geography curriculum, it is easier to contextualise topics for higher-order knowledge construction (Gibbons 2000). In fact, there is no reference in the CAPS on how IK should be integrated throughout a calendar year in the curriculum (Republic of South Africa 2011c).

In the South African school context, besides the difficulties and barriers with GIS implementation, it is also the teaching through GIS (Breetzke, Eksteen & Pretorius 2011; Fleischmann 2012) and IK that is not integrated into suitable Geography themes. Both these problems can be addressed by the effective use of easily accessible and navigable free web-based software and applications with access to local data. Geographical Information Systems is not a prerequisite for the integration of IK in Geography lessons, but according to Bornman (2018), it may afford teachers and learners the opportunity to study the subject in context and to incorporate local and IK in the learning process while using GIS, thus, teaching through GIS.

A valuable way to integrate IK with technology into the curriculum is, thus, with the use of GIS and Google Earth and Maps. Working with map skill-related tools and applications, such as GIS, Google Earth and Google Maps, falls within the spectrum of spatial thinking, which is being recognised globally as a valuable aspect of problem-solving within a wide selection of academic disciplines (Lee & Bednarz 2009:183). Spatial thinking is a multifaceted concept consisting of several factors, including spatial visualisation, spatial orientation and spatial relations (National Research Council 2006), all needing higher-order learning skills that can be learnt and taught formally to students, using appropriately designed tools, technologies and curricula. It is within this domain that IK can easily be integrated in teaching through GIS (especially Google Earth) in certain geographical themes. Geographical Information Systems has become a welcome tool for teachers in the current digital and information-saturated era to foster learners' critical and metacognitive thinking abilities, sorting through an overabundance of information (Goldstein 2010).

Finally, in practice, it is quite possible to teach integrated GIS and instil IK into the Geography classroom by utilising Google Earth and Google Maps on different platforms as mediation tools. By linking modern technology with established map skills and IK in a multidimensional reality, Geography teachers may be able to improve the SDL and map work skills of learners while allowing learners from all cultural spheres to participate by accommodating their perceptions and knowledge systems. Including IK in the class through GIS and map work may make the technology more understandable to learners as they would be able to learn GIS concepts and functions while focussing on something they find familiar (Bornman 2018). It is therefore a great opportunity to teach and learn about IK through technology applications in Geography and at the same time foster valuable SDL skills for learners of students.

Recommended technological interventions for indigenous knowledge in teaching practice

From the above, the following recommendations can be made for possible technological interventions for IK in teaching practice:

- Focus should be on appropriate technologies when incorporating technology in IK as appropriate technologies allow for efforts in communities to be sustainable.

- The technology interventions (albeit e-technology) should be focussed on empowering the community, limiting environmental impacts and increasing sustainability, which should result in capacity-building and empowerment.
- Some e-technology examples that have been suggested include Internet access, communications technology such as two-way video feeds and video conferencing, and mobile technology in the form of iPads and tablets.
- Computer technology can significantly improve the lives of indigenous people. Improved access to communications technology and computers in schools and communities enable residents to remain in their communities while undergoing necessary training.
- Using open-source software is important for creating online content relating to IK. Access to technology in education can assist in incorporating indigenous languages into the classroom.
- Make use of free technology applications such as Google Earth and Maps to foster map work and SDL skills with themes, wherein IK can easily be integrated, challenging learners to incorporate their own experience systems into multicultural learning environment contexts.
- The affordances technology could provide in terms of the accommodation of indigenous languages as carriers of indigenous culture and knowledge should also be considered.
- The potential for Open Educational Resources (OERs) as a means for sharing, reuse and publication of IK should not be underestimated. The William and Flora Hewlett Foundation (2018) defines OERs as 'teaching, learning and research materials in any medium – digital or otherwise – that reside in the public domain or have been released under an open license that permits no-cost access, use, adaptation and redistribution by others with no or limited restrictions'. In this way, the preservation of IK can be supported.
- Archiving or storing IK for educational purposes by means of technology should be done in consultation with IK holders. Shizha (2016:57) also highlights the concerns regarding the dispossession of traditional knowledge. Therefore, proper acknowledgement and negotiations on

including IK in repositories are imperative. This can also help to protect and acknowledge the holders of a particular intellectual property.

Conclusion

In conclusion, this chapter focuses on the affordances of technology for teaching IK. The research was theoretically underpinned by literature on SDL, educational technology and IK systems. From a review of CAPS, the relevance of IK systems was evident, and an appropriate policy framework exists where SDL can be fostered and technology can be implemented within the South African school context. The DBE's PDFDL is also a further extension of how the inclusion of technology can be supported.

This chapter also explored technologies and teaching–learning strategies that support the teaching of IK, as evidenced from current literature. To this end, appropriate technologies and ITs for IK were defined and set characteristics were identified. The parameters of what ITs would entail were also set out, whereafter examples of relevant technologies were presented. Furthermore, a critical review of the existing literature was presented. From this review, it was evident that the research on IK, and especially technology in IK, has a broad scope. The importance of IK is clear; yet, the implementation of IK in the curriculum has been insufficient. From the review, the infusion of IK into Life Sciences, Natural Sciences, Mathematics and Technology education is proven. Most of the literature in the search results focussed on appropriate technologies as opposed to ITs. The link between appropriate technologies and IK was also established. The most prominent characteristic in the review was the engagement of the community, and this seems to be a possible point of further investigation. Most of the reviewed literature focussed on the South African context. In terms of technology, the focus was on ITs and computer- and Internet-based technologies. The teaching focus in the review was on teacher training, education outside of teacher education and, the largest component, teaching in practice.

The chapter concluded with recommended technological interventions (specifically also in Geography) for IK in teaching practice based on the literature overview and critical review of the identified sources. It is therefore evident that clear affordances of technology for teaching IK can be identified, but that further development, support and research are necessary in this regard.

Summary

In this chapter, the affordances of technology for teaching IK are explored. The use of technology provides unique opportunities to embed IK in different subjects while adhering to blended learning, e-learning and SDL principles as set out in the relevant literature. Also, within the context of teacher education, relevant curriculum policy documents were analysed. This research aimed to determine, by means of a critical review of existing research literature, how the inclusion of IK in different contexts can be supported by employing various technologies. Drawing from the lack of empirically investigated practices that foster SDL while supporting the integration of IK using technology in different subjects, a number of recommendations are made in this chapter.

Chapter 11

Indigenous knowledge research ethics

Melissa Speight Vaughn
Research Unit Self-Directed Learning, Faculty of Education, North-West University, Potchefstroom, South Africa

Marry Mdakane
Research Unit Self-Directed Learning, Faculty of Education, North-West University, Potchefstroom, South Africa

Introduction

> *Come through the door not the window*
> Steenkamp (n.d.)

Andries Steenkamp was a respected leader in the San community. His dedication towards protecting his people is memorialised in the San Code of Ethics (SASI 2017). In a publicly available video interview conducted with San leadership, Steenkamp (in Vaalbooi n.d.) used the metaphor of a house to describe San IK research ethics:

> If you want to get something useful you first need to put your own house in order. Your house must have a door, so that nobody needs

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> to enter by the window. You must come in via the door; that is to say via the San Council. We do not ask for money, not at all. It has never happened that the San Council asks money for research. (n.p.)

Ethics of mutuality, respect and reciprocity are embedded in the metaphor. Steenkamp cautions us to exhibit respect and reciprocity in research engagements. Based on the San indigenous perspective of shared existence, he recognises that different knowledge houses exist; however, respect is necessary in that shared existence. Everyone is deserving of the respect and decency of a proper entrance. However, this is a grace not historically extended to San people (Barnard 1992:5; Mountain 2003:1). His story admonishes the lack of respect exhibited by researchers not following prescribed channels of ethical research. A history of individual and collective experiences of ethical abuses is embedded in the text of the San Code of Research Ethics.

The *Nature* journal stated that San Code of Research Ethics is the first indigenous code of researcher ethics in Africa, designed to protect San IK and people (Callaway 2017). The San indigenous people of South(ern) Africa have endured a history of assault on their IK, traditional communities and ways of life. Most recently, four members of the San community were exploited in genome sequencing research (Schroeder et al. 2016:36). The stated purpose of the research was to 'characterise' genomic diversity of Southern Africans to support their inclusion in medical research innovations (Schuster et al. 2010:943). The research project adhered to institutional research ethics policy and was approved by institutional review boards in three countries, namely, South Africa, the United States of America and Australia, *without* consultation with the San leadership. The researchers published the genetic findings of the research as well as a supplementary document in *Nature*, a peer-reviewed academic journal. The document made unsubstantiated claims, pejorative assumptions and stereotypical assumptions that were generalised across the San population (Schroeder et al. 2016:37). The document strayed from the stated research focus and resulted in collective embarrassment, discrimination and psychological harm to the

San community. This violation is one event in the history of unethical research on holders of IK.

San leaders challenged the ethical validity of the research but to no avail. Members of the leadership council contested the consent procedures and repeatedly requested access to informed consents and research documentation. The requests were denied as researchers attested that verbal consent was granted by participants. The then Deputy Director of the Working Group of Indigenous Minorities in Southern Africa, Mathambo Ngakaeaja, formally addressed the arrogance, ignorance and cultural myopia demonstrated by the researchers and the institutions (Schroeder et al. 2016:37).

The genome research is not an isolated event in San history. The San peoples are among the oldest indigenous communities in South Africa (Barnard 1992). All extant humans are believed to have evolved from the ancestors of the San (Krueger 2011), and they hold IK essential for environmental sustainability (Schroeder 2009:11). Historically, they are adept hunters in desert climates such as the Kalahari Desert. Their IK includes the use of the succulent *Hoodia gordonii* to sustain them on day-long hunting journeys. Measured consumption of the desert succulent maintains clarity as well as suppresses hunger. Unbeknown to the San community, the CSIR of the South African government secured a patent for the commercial use of *Hoodia* as a dietary supplement. The government agency sold the patent to the pharmaceutical company Phytopharm (Tellez 2007:1). Governmental and corporate agencies gained material wealth from San IK with little benefit to the San community.

The genome research and *Hoodia* theft emerge from the struggle between knowledge and power in former colonised territories. Western knowledge has power in the academy, whereas IK is excluded (Canham 2018:4; Odora Hoppers 2001:78). It is important to note that the behaviour of the genome researchers was sanctioned by foreign institutional review boards and ethics policies, even though it was in violation of local San IK research ethics.

This suggests that social and political shifts that recognise IK as national and academic assets may not be sufficient in stemming ontological violence against historically oppressed groups of people; decolonisation of institutional ethics review processes generally, and institutional research ethics specifically, holds potential for improving the relationship between IK communities and academic research institutions. Research ethics policies influence major aspects of research design such as problem posing, community engagement and data collection activities; however, scant literature examines the impact of decolonisation on institutional research ethics policies.

Institutional research ethics policies that do not consider IK research ethics may allow colonial practices to continue through educational research (Battiste 2005:2; Smith 1999:24). Arguably, the lack of such examination perpetuates economic, educational and social inequities in previously colonised countries, which are exacerbated in emerging first-world nations such as South Africa, where a diversity of IK groups exists (Ntuli 1999; Odora Hoppers 2001; Vilakazi 1999), thus making IK research ethics an important issue in the decolonisation of institutional research ethics policies and practices.

This research views institutional research ethics policy through a postcolonial indigenous lens, which recognises the historical struggles and epistemological conflicts that are at the heart of the process of inclusion of IK in institutional policies and research practices. Postcolonial indigenous thought interrogates the relationship between power and knowledge in the research ethics process, as well as in researcher practice (Chilisa2012:19).

The authors were guided by two main research questions:

- How does an institutional research ethics policy integrate IK research ethics in policy?
- How can the roles and responsibilities of academic researchers be answerable to IK research ethics?

To this end, the authors investigated the alignment of institutional research ethics policy with IK research ethics and then examined our academic roles and responsibilities in IK research ethics. This investigation is purposed to inform academic debates on the decolonisation of institutional research ethics policy.

The main purpose of this chapter is to investigate decolonisation from a policy perspective to determine the recognition of IK, acknowledgement of IK research ethics and the inclusion of indigenous ways of knowing into institutional research ethics policy. This investigation and discussion consider the effects of institutional research ethics policies in the continued marginalisation of IK research ethics.

Background context

In South Africa, the relationship between institutions of higher education and IK groups was shaped by colonialism and moulded by apartheid (Heleta 2016:1; McKaiser 2016; Ramoupi 2014:5). Both systems advanced the idea of white supremacy and inferior others (Cesaire 2000:43). Colonialism established a knowledge hierarchy that instituted European ideologies and subjugated local knowledges, and the apartheid regime 'entrench(ed) the power and privilege of the ruling white minority' (Bunting 2004:52; Pietsch 2013). The explicit structures of these systems are no longer visible, but the ideologies are inscribed into educational institutions as universal truths (Kelley 2000:27). The South African university system served to 'construct and maintain the social, political and economic features of the apartheid order' (Gibbon & Kabaki 2004:123). Systemic disqualification of the black majority and IKs went hand-in-hand, resulting in the exclusion of IKs from the universities. Eurocentrism was the 'epistemological truth' (Motta 2013:97) undergirding all aspects of education, including curriculum (Jansen 1998:111; Zeleza 2009:133), research (Datta et al. 2015:581; Owusu-Ansah & Mji 2013:1) and institutional culture (Jansen 2012:18). Such a system reproduces itself while simultaneously silencing other knowledges and ways of thinking (Kaya & Seleti 2013:34). Epistemological violence of erasure, exclusion and insecurity are arguably the most destructive and long-lasting effects of these oppressive systems (Shiza & Kariwo 2006:20).

Epistemological violence is defined as social-historical processes of imperialistic, epistemic inscription (Spivak 1994:80). Inscription of one knowledge results in the violent subjugation of other ways of knowing. It erases the history of indigenous peoples (Wilson 2004:359) and precludes critical interrogation of the 'outcomes of a history of patriarchy, slavery, imperialism, colonialism, white supremacy and capitalism' (Molefe 2016:32). In post-1994 South Africa, decolonisation efforts should aim to disrupt 'the political economy of knowledge' (Dei 2000:129) by rejecting Euro and Western ideologies as the only way of knowing (Pillay 2015; Zeleza 2009:116). Decolonisation processes clearly define African people, knowledges and histories as the centre of a universe and, thus, the university (Mbembe 2016:35), as opposed to Europe being the centre of an African reality (Ngugi 1981:93). In research, rejecting Eurocentric philosophies restructures the research process as well as the institutional ethics process (Tauri 2018:1). Aboriginal, First Nations and indigenous scholars from the United States, Canada and Australia have advanced the decolonisation discourse about institutional ethics policies (Bull 2010:13; HRCNZ, IHRC 2004, WUN). Voices from the African context are largely absent from the discourse on decolonising institutional research ethics.

■ Theoretical framework

Postcolonial indigenous theory and discourse analysis theory comprise the theoretical framework for this decolonisation project. Decolonisation is closely aligned with anticolonial processes; it emerged in formerly colonised territories to honour, reclaim and centre historically repressed IKs, people and lands (Denzin, Lincoln & Smith 2008; Smith 1999:20). Recovery of indigenous ways of knowing in higher education can potentially foster holistic relationships between people, environment and cosmos (Datta 2018:2). Emanating from a relational ontology, IKS prioritise communal knowledge acquisition in contrast to individualistic pursuits of universalising abstract knowledge that dominates Western philosophical orientations (Simpson 2004:374). Struggles of knowledge and power are embedded in decolonisation processes in academia where Western knowledge systems were institutionalised in academic processes of research and practice (Smith 1999:26).

Postcolonial indigenous research

The exploration of IK research ethics relies on postcolonial indigenous thought to interrogate institutional research ethics policy as 'a significant site of struggle between the interest and knowing of the West and the interest and knowing of the other' (Smith 1999:2). The postcolonial indigenous paradigm takes a culture-specific approach towards decolonising universalisms and totalising different forms of knowledge production. Indigenous knowledge is the cultural reference capable of illuminating the historical patterns of power and knowledge that reproduce deficit thinking and pathological descriptions of the former colonised territories (Chilisa 2012:24). The aim of postcolonial indigenous theory is reconstructing knowledge in the interests of historically oppressed people (Chilisa 2012:13).

Postcolonial indigenous research prioritises relationality in the research for IK. Relationality assumes that all aspects of life exist in a nexus of relationships (Wilson 2008:69). Holism is mutually constituted through relationships in, and between, people, history, culture, place, knowledge and social processes (Martin & Miraboopa 2003:205). Relational ontology is grounded in relationships between individuals and the collective, where individual rights and responsibilities are infused with those of collective well-being. Knowledge is rooted in lived experiences and cultural ways of knowing and being and is useful for the whole (Wilson 2008:70). Concepts of respect, reciprocity, responsibility and rights are informed by indigenous ways of knowing.

From a postcolonial indigenous perspective, researcher roles and responsibilities extend beyond those required from Western axiological paradigms. Researchers are viewed as 'knowledge brokers' with power to legitimate indigenous ideas (Foucault 1977:27). Researchers are viewed as 'healers' with the responsibility of 'realigning' people to the natural order of the universe (Ramsey 2006). Such roles and responsibilities suggest that the process of decolonisation is not solely an institutional responsibility — both the researcher and the research must be decolonised as well (Datta 2018:2). Chilisa (2007:18) proposes that researchers engage in continual 'self-reflection and self-questioning' of research events and outcomes throughout the research process. She suggests that, in this 'back-and-forth' review and analysis, researchers examine their relationship with knowledge and power by interrogating colonisation roles and ethical responsibilities towards indigenous people and IK.

As academics, we accepted to interrogate our role as colonised or coloniser in this research by asking which side we are on and what needs to change? The first author is a black female postdoctoral researcher from the United States conducting research with indigenous groups in South Africa. The second author is also a black female researcher from South Africa who has experienced the apartheid regime. She is also a faculty member of the institutional research ethics committee. We combined research ethics, experiences and praxis from global north and global south contexts, recognising the importance of inclusion of IK in institutional research ethics policy. We engaged the San Code of Research Ethics and translated interviews with San leaders as oral texts of San IK research ethics. The San text served as a lens to examine the North-West University (NWU) research ethics policy through qualitative research methods. As authors, we do not advance superiority of IK; instead, we seek a relational collaboration of epistemologies focussed on interconnectedness, not competition.

Methods

The primary purpose of this research was to critically examine institutional research ethics policy from a San indigenous cultural referent to discuss decolonisation of institutional research ethics policy. Data included two policy documents, two interview videos and researcher notes. The qualitative data were interpretively analysed to answer the research questions. A qualitative interpretive analysis of two policy documents was used to answer the primary research question: How are IK research ethics integrated into the institutional research policy? Elements of discourse analysis informed our interpretation of meaning embedded in the discourse of the policy. According to Codd (1988:237), policies serve political purposes of masking social conflict and fostering commitment to the notion of universal public interests. We argue that institutional research ethics policy may be a site of struggle where systemic violence is maintained.

In postcolonial societies, texts provide reflections of the interconnected relationships between knowledge, power, social structures and language. Foucault (1972:205) asserted that the language of texts is socially constructed and intertwined with structural elements of social life. Texts are interactive meaning-making processes that are considered social events (Fairclough 2003:8). Imbued with social character, texts can be considered social events with 'causal effects', resulting in changes in knowledge, behaviour and social relations (Halliday 1994:22). The text of indigenous and institutional research ethics policies impacts research in, and with, IK groups.

Critical analysis is an interactive meaning-making process that occurs in three analytical events, namely, production, text and reception (Fairclough 2003:27). The production of the text focuses on the producers of the text, specifically how their intentions and identity are incorporated into the text. Institutional position, values, beliefs and desires influence the production of the text. These elements are mostly processed internally in the authors' minds. The second element of meaning-making is the text itself. Meaning-making depends on explicit text of what is stated as well as implicit assumptions about what is not stated. Interplay between assumptions, intentions and language contribute to meaning-making and reception of the text. The last analytic process is the interpretive work of the reader.

This analysis operationalised postcolonial indigenous theory in the analysis of research ethics policies. We argue that institutional research ethics policy can be a site of struggle where systemic violence is maintained. Data included The San Code of Research Ethics and the North-West University Education Research Policy, which were examined for alignment. This line of analysis disrupts the flow of knowledge from the institution onto IK groups.

Analysis proceeded individually and collectively in a sequential manner. Each author read and interpreted both policies and documented their interpretations and understandings of ethical principles advanced in the policies. The San Code of Research Ethics was read and interpreted prior to the NWU Policy and Rules for Research Ethics. Then, the authors discussed alignment and recommendations. By applying indigenous perspectives to institutional policy, we hope to illuminate deeper problems and conflict in research ethics policy and contribute to knowledge restructuring aspired by postcolonial indigenous theory. The next two sections of the chapter are devoted to our synthesised interpretations and discussions of the policies.

■ The policies

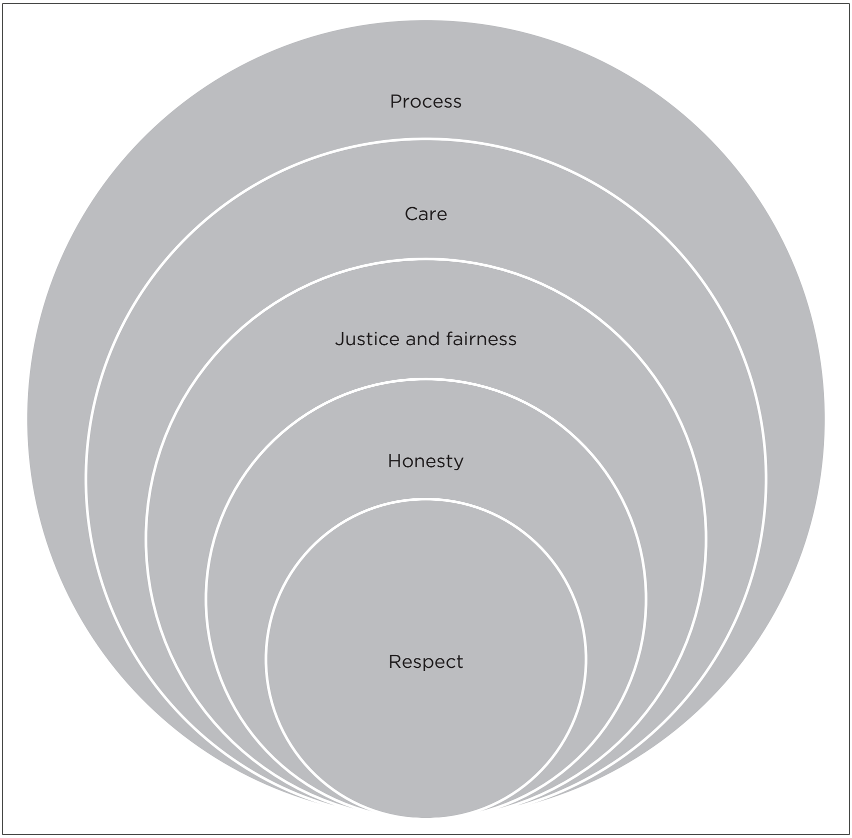
This section reviews the ethical tenets of the San Code of Research Ethics and the NWU Rules and Policy for Research. More focus was afforded to the San policy, which serves as the cultural referent for this policy analysis.

San Code of Research Ethics

On March 2, 2017, the San leadership Council of South Africa publically launched the San Code of Research Ethics (Callaway 2017:475). The document provides researchers a framework for conducting ethical research with San communities. It draws on a foundation of San IK for the purpose of protecting San people, preserving San knowledge and repairing San dignity. The code was developed in response to exploitative, inappropriate and pejorative research conducted by unscrupulous researchers. It was preceded by traditional San leadership that governed the well-being of the San people. The written document was intended to stem the tide of ethics dumping and damaging research conducted using San people.

The code advocates for constructive relationships between the researcher and the community. Principles of participation and protection ensure research is in the best interests of the San community. Researcher roles and responsibilities are framed within the collective process of research design, data collection and publication. Researchers are tasked with cultural and social responsibilities throughout their engagement with San leadership and communities. The code requires cultural, historical and linguistic sensitivity when engaging with San communities. It requires researcher transparency and humility throughout the process. Violation of the stated roles and responsibilities carries consequences for researchers and research institutions.

Tenets of the San Code of Research Ethics are fundamental to life and sustainability. San ways of life are preserved through collective approaches of *research with* as opposed to *research on* San IK holders. Concepts of respect, honesty, justice and fairness, care and process are interrelated in ethical research. The tenets cannot operate in isolation; rather, they rely on each other for meaning and execution of ethical research. The authors created a visual representation of how the tenets exist relationally. Figure 11.1 demonstrates the interconnected relationship in and between the tenets. The following review of San ethical tenets should be understood based on the relationality of the tenets.



Source: Adapted from SASI (2017).
FIGURE 11.1: Relationship between tenets of San Code of Research Ethics.

Tenets of San indigenous knowledge research ethics

Respect

We require respect not only for individuals but also for the community.

The San Code of Research Ethics foregrounds collective and inclusive research as ethical. Respect is defined as actions of responsiveness, deference and reverence. Researchers are required to be socially and culturally responsive in research with San communities. San people and IK are central to all investigations and deference is demonstrated to San culture, history and 'relationship with the environment' (SASI 2017). Respect requires San participation as co-researchers in all aspects of research to monitor researcher responsibility.

Honesty

- *We require honesty from all of those who come to us with research proposals.*

Honesty is hinged on the principle of respect. Honesty necessitates transparency and continued communication. The code specifies clear and open exchange of proposed research. Researchers are admonished to avoid academic language and jargon that hinder clear communication exchange. San leadership and participants should have linguistic access to the research proposal for the purpose of accessing the ethicacy of the research. This cannot occur without researcher transparency regarding risks and benefits. Continual conversation throughout the research process is required to maintain ethical standards.

Justice and fairness

- *We require justice and fairness in research.*

The tenet of justice and fairness is connected to honesty. Full disclosure of how the research benefits the entire San community is expected. Justice and fairness are executed through the use of mediation and dispute resolutions, as violations of the code carry consequences for individual researchers and institutions.

Care

- *Research should be aligned with local needs and improve the lives of San. This means that the research process must be carried out with care for all involved, especially the San community.*

Caring in research comprises caring for the entire San community. Families, and social and physical environment, are included in the community. Research that does not consider the web of relationships between people, place and society may be deemed unethical by San standards. Well-being for the San includes the social welfare of the collective and the environment.

Process

- *Researchers need to follow the processes that are set out in our research protocols carefully, in order for this Code of Ethics to work.*

Process references the collective responsibility of both San and institutional research community. This tenet may denote the interconnectedness of the previous ethical tenets. Process reiterates the primary focus of repairing relationships between San and institutional research communities.

North-West University Research Ethics Policy

NWU is a 'pre-eminent University in Africa [...] with a unique institutional culture based upon the values the University espouses' (North-West University Institutional Office n.d.: Preamble). The institutional research ethics process is regulated by the Policy and Rules for Research Ethics (PRRE). The policy dictates the rules, management and procedures of the university ethics process. The policy statement is regulated by the Department of Research Support and monitored by the department director. The accountable executive manager is the deputy Vice-Chancellor of Institutional Research, Innovation and Community Engagement. The most recent policy was adopted on 17 November 2016 and scheduled for review in 2019. The Rules for the Management of Research Ethics

(North-West University Institutional Office n.d.) defines research ethics as the following:

> Research ethics deals with the way in which research is planned, conducted and executed, in order to ensure that the entire process conforms to rules, standards or norms for conduct as agreed upon by the research community at large. (p. 3)

The 'research community at large' is not specified in the document. Ethical guidelines and researcher responsibilities as specified in the policy and Code of Conduct are reviewed in this section of the document.

The policy is influenced by national and international forces and should be read in conjunction with supporting documents. The text is informed by 'national and international ethics standards, statutory requirements and ethical principles derived from the Vision and Mission of the NWU' (North-West University Institutional Office n.d.:n.p.). It is aimed 'to ensure that all research conducted at and by the NWU are conducted in line with ethical principles' (North-West University Institutional Office n.d.:n.p.) and aligned with the *National Health Act* of 2004. The document instructs researchers to read it with the Institutional Research and Innovation Strategy and the NWU mission.

The policy document specifies that research ethics should be guided by three principles, namely, beneficence, justice and respect. These principles compel researchers to assess 'projected' benefit and 'potential' harm, balance potential risks and benefits among role players and treat participants as autonomous agents. While the document does not reference the researcher Code of Conduct as an accompanying document, it is attached to the Policy and all researchers are required to consent to as part of the research ethics approval process. The Code of Conduct specifies 'four major principles of research integrity', namely, honesty, accountability, professional courtesy and good stewardship. These principles are followed by 14 ethical responsibilities for researchers during research.

Ethical principles outlined in the policy document provide the foundation for the researcher Code of Conduct and ethics management oversight. The principles are loosely connected and generally lack consistency. All of the principles are not mirrored in the Code of Conduct principles or responsibilities. For example, the policy outlines beneficence as an assessment of benefits and harms in the proposed research. The Code of Conduct principle of good stewardship of research on behalf of others can be interpreted as assessing benefits and harms, but no correlated responsibility is listed. Code of Conduct principles were general and fluid in meaning, with each principle correlated with multiple policy principles and Code of Conduct responsibilities. For example, the Code of Conduct principle, 'good stewardship of research on behalf of others', is ambiguous. It can be interpreted to mean beneficence, justice or respect. In a similar manner, 'others' can be interpreted as research participants or research colleagues. Table 11.1 is intended to highlight the principles across the three documents and demonstrates a lack of ethical cohesion.

The NWU PRRE is a tripartite document. The policy preludes the Code of Conduct and the Rules for the Management of Research Ethics at the NWU. The latter document is by far the most extensive of the three. The policy was designed to govern research in multiple disciplines, which may contribute to the non-specific language. Ethical principles and responsibilities are not aligned across the documents. The Code of Conduct responsibilities specify duties specific to academic responsibilities. The lack of ethical cohesion across the documents may signal a lack of alignment with San IK research ethics. The next section examines the alignment between the two documents.

TABLE 11.1: Ethical cohesion.

NWU rules and policy	Code of Conduct (ethical principles)	Code of Conduct (responsibilities)
Beneficence: assess projected benefit versus potential harm	Good stewardship of research on behalf of others	
Justice: risks and potential benefits balanced	Good stewardship of research on behalf of others	I will disclose all conflicts of interest (financial and other) that could compromise the trustworthiness of my work in research proposals, publications, public communications and in review activities. I will at all times weigh societal benefits against the risks inherent in my work.
Respect for research subjects: treat participants as autonomous agents	Professional courtesy and fairness in working with others Good stewardship of research on behalf of others	
	Honesty in all aspects of research	When I publically address a community in the spirit of academic freedom, I will in all stages base my professional comments on research findings (if applicable) and my expertise. I will distinguish between professional comments and opinions based on personal views. I will endeavour to create and sustain an environment that encourages research integrity through education of students, research teams and peers, as well as abide by policies and reasonable standards for advancement.
	Accountability in conduct of research	Should any irresponsible research practices and/or research misconduct become known to me or brought to my attention, I will report such irresponsible research activities to the appropriate authorities. I will respond to irresponsible research practices or conduct, by taking prompt action as set out in the procedures of the university. I will also protect those who report misconduct in good faith, to the best of my abilities.

Table 11.1 continues on the next page →

TABLE 11.1 (Continues...): Ethical cohesion.

NWU rules and policy	Code of Conduct (ethical principles)	Code of Conduct (responsibilities)
	Professional courtesy and fairness in working with others	I will, where applicable, share my data and findings openly and promptly, in line with external funding rules. This will be done as soon as possible after I have had an opportunity to establish priority and ownership claims. I will take responsibility for my own contributions to publications, funding applications, reports and other representations of my research. I will also, and only, include authors who meet valid authorship criteria. I will acknowledge the names and roles of those who made significant contributions to my research in publications, including writers, funders, sponsors and others, who do not meet authorship criteria. In my peer reviews, I will provide fair, prompt and rigorous evaluations, and I will respect confidentiality when I review others' work. I will at all times employ appropriate research methods, base my conclusions on critical analysis of the evidence and report my findings and interpretations fully and objectively. I will take responsibility for the originality and trustworthiness of my research. I will stay abreast of, and adhere to, all institutional, national and international laws, regulations and policies applicable and related to my research. I will keep clear and accurate records of all research that I have conducted in a manner that will allow verification and replication of my work by others, if applicable.

Source: Adapted from North-West University Institutional Office (n.d.).
NWU, North-West University.

Discussion

This chapter began with Andries Steenkamp's metaphorical reference to the ethical responsibilities required in research with San communities. His metaphor demonstrates a relational perspective of research and is useful in discussing the alignment with the NWU PRRE. 'Coming through the door' is demonstrative of human relationships. Entering through the door requires responsibility from both parties, while entering through the window is laden with ill will and cruel intentions. In this discussion, the door is symbolic. The door is indicative of entering into the San IK community, where indigenous ways of being are central to understanding the world. There is also a door for entering the academy. The metaphor of the door is woven throughout this discussion of IK research ethics. The discussion is guided by the following question: 'How does the NWU policy integrate IK research ethics?' Our interpretive analysis revealed that IK remains marginalised in the policy language, pursuits and responsibilities. The policy maintains a Western philosophical foundation rooted in universalism, individualism and disciplinary knowledge. The policy does not explicitly mention the needs of IK groups nor does it reference IK research ethics. The NWU policy governs the way that research ethics is practised at the university and prescribes rules for researchers' interactions with research 'subjects'. The San Code provided a perspectival vantage point to view not only the institutional policy but also our roles as academics and researchers. This research was designed to examine the relationship between the policies of two entities (San IK community and an academic institution) as related to research ethics, but we could not ignore the fact that researchers were caught between the two worlds, compelled to choose sides. We questioned our academic role and responsibilities in conducting research with IK groups and offered recommendations for decolonising the NWU PRRE and restructuring the knowledge of research ethics. The discussion proceeds by answering the research question. This discussion is specific to the cultural-historical relationship between the San IK group and the NWU, which may not apply to other indigenous groups or academic institutions. This section concludes with recommendations for integrating San IK research ethics into the NWU research ethics policy.

Alignment

The San Code emanates from a relational ontology, and therefore, it focuses on relationships. Based on lived experiences with research institutions, the code prioritises the relationship necessary for ethical research. It holistically addresses the interconnected dependency between the San community, research institutions and the environment.

The NWU fostered an individualistic philosophy. The researchers are tasked with disciplinary and academic knowledge relative to their field. They are also responsible for the integrity of their research as well as the reporting of any misconduct to the 'proper authorities' and to manage misconduct reported by the participants. The policy does not state if the university offers support or consultation for researchers. The researcher assumes responsibility for not causing harm during the research process. This is not aligned with the San communal approach to research, which advocates for full participation in the research design, research activities and publications. This level of involvement is not considered in the NWU policy. The policy assumes that the researcher is the holder of knowledge in the research relationship, which discredits IK ethics and ethical protocols.

The San Code demonstrates holistic knowledge. Holism is an additional dimension of relationality that includes sacred and secular worlds (Hoffman 2010:123). A foundation of IKS is the inseparability of spiritual, physical and human realms (Blackstock 2007:67). The San Code references these dimensions under the principles of respect and care. The code specifies who and what should be respected and how respect is demonstrated. 'We require respect not only for individuals but also for the community' (SASI 2017). According to the code, respect includes cultural, historical and IK domains. Care includes cultural and social and physical environments.

Holism and relationality are also evident in the conceptual alignment and generalisability of the San document. As discussed in the previous section, tenets of the San Code are interrelated and interdependent in definition as well as action. Conceptual alignment fosters deeper understanding of the tenets as well. The code is not disciplinary-specific; instead, it generalises to types of research because it focuses on the San people as the knowledge holders. The code foregrounds respect as the foundation for an ethical research relationship, which applies to well-being and relationships in general.

The authors noted linguistic variance between the San Code of Research Ethics and the videotaped interviews with San leaders. The San Code was penned in English and the videos were recorded in Afrikaans with English subtitles. Neither of these languages are indigenous San languages. However, the genocidal campaigns against San culture, languages and people effectively wiped out the use of their Xam language prior to 1910, with the exception of a section of San people in the Northern Cape province that maintained the language (Mountain 2003:36). The language content and context of both the code and the video have been approved by the San Council.

According to the NWU policy, researchers should respect research subjects as autonomous agents. This does not respect the collective orientation of San communities. The communal generation of knowledge is not recognised in the language of the documents, and the role of IK gatekeepers is not acknowledged as part of the research process. Respect in the research relationship is left to individual discretion in the NWU policy. Who and what should be respected are not defined in the document. While the institution requires 'full disclosure of conflicts of interest that could compromise the trustworthiness of my work', work is specified as academic pursuits that include 'research proposals, publications, public communications, and in review activities' (North-West University Institutional Office n.d.:n.p.). This does not explicitly state responsibility to IK leadership or participants.

Recommendations

Integration of IK into the NWU ethics research policy begins with alignment with IK research ethics. The San Code for Research Ethics is the first such formal code in Africa. It follows research ethics codes created by aboriginal and indigenous peoples in Canada and Australia, where Maori, Inuit and Metis people defined the research interests of the community and prescribed the research process within their communities (Absolon 2008:52, AIATSIS; Bull 2010:13; Ermine 2000:7). The authors contend that universities regard the relevance of IKs in reforming higher education. Analysis of the alignment between the documents resulted in three recommendations to foster a healthy research relationship between the NWU and the San IK community. The recommendations follow Andries Steenkamp's metaphor: the house, the door and the window.

The house

According to Steenkamp, 'you first need to put your own house in order' (Andries Steenkamp, San leader, date unknown). His reference to the organisation of San leadership in the creation of the research ethics code is a useful instruction for the authors of the NWU research ethics policy and probably for other South African universities as well. The NWU research ethics policy is spread across multiple documents. In addition to being difficult to find on the Internet, the documents reference materials that are not available online. Each document specifies different ethical principles. They do not align with each other. Following Steenkamp's advice, the NWU policy needs to be reviewed for internal consistency.

The PRRE is the guiding document for the researcher Code of Conduct and the Management of Research. The documents focus on managing the research process exclusive of the communities that are impacted by the research. The singular focus of the documents misses a holistic perspective on research. The policy is fragmented, segmented and disciplinary in line with a European or Western philosophical framework, a framework that is not contextualised for African IK research. The document is responsive to research institutions, not people.

The door

Acknowledging the leadership of IK groups must be reflected in the document. San leadership or traditional leadership should be included, from the early stages of research design through the entire process, including publications. Acknowledgement of IK groups is synonymous with entering through the door.

The window

The NWU research ethics policy should be answerable to the populations most ravaged by research within the borders of South Africa. Indigenous people, knowledge and land have been under attack since the early stages of colonisation (Odora Hoppers 2001:74). In South Africa, IK was labelled witchcraft and punishable by law (*Witchcraft Act* of 1957). Universities and research institutions share some responsibility for supporting derogatory stereotypes and misrepresenting indigenous people. Often, in the past, research institutions have unethically entered through the window of IK communities. Recognition of social and historical flaws demands answerability to these communities. Importing the knowledge and policies of other world countries does not answer the unique social problems facing Africans or Africa. Ethical research should be contextualised to Africa generally and South Africa specifically.

An example from ethnobotany

This research is purported to contribute to decolonisation efforts specific to institutional review processes. While the authors focus on educational research specifically, we do not contend that IK research ethics are not occurring at any South African university. The following example from an ethnobotanical study does adhere to IK research ethics. The researchers assumed the role of knowledge brokers in their projects. The example below is a useful exercise for researchers engaging in research with IK groups.

De Beer (2012) and De Beer and Van Wyk (2011) conducted ethnobotanical research among people of Khoi-san descent in the Northern Cape (refer to Ch. 4). Ethical clearance was obtained from the University of Johannesburg, but these authors furthermore were guided in their research by the Code of Ethics of the International Society of Ethnobiology. Table 11.2 assesses their research methodology and ethics, according to the tenets of the San Code of Research Ethics document.

The San Code of Research Ethics stands alone amid a vast array of African IK communities. Inclusion in the university is mandatory if research is responsive to national and global problems. Following the San Code of Research Ethics, San representatives should be welcomed to the university review sessions. They should have a voice in rewriting the ethics policy that includes IK research ethics.

The most recent NWU research ethics policy was accepted prior to the launching of the San Code of Research Ethics. It is our hope that the following recommendations will be considered at the upcoming review and incorporated into the policy.

TABLE 11.2: The research of De Beer and Van Wyk (2011) through the lens of the San Code of Research Ethics.

Tenets of San Code of Research Ethics	**Compliance by De Beer and Van Wyk (2012)**
Respect — being socially and culturally responsive	Indigenous knowledge regarding plant use is often exploited by pharmaceutical companies. A classic example is the commercialisation of the *Hoodia* plant and the work of the South African Council for Scientific and Industrial Research (CSIR) who patented the active ingredient P57, and eventually granted a license to Pfizer to develop it as an appetite suppressant (which did not work out as planned). The San people felt that they were not equal stakeholders (as holders of this indigenous knowledge) in the process. A problem in identifying the rightful holders of this indigenous knowledge was, of course, that indigenous knowledge is often an oral tradition. The work of De Beer and Van Wyk (and other ethnobotanists) is significant, in so far as the intellectual property (IP) of holders of indigenous knowledge is recorded. It then serves as a published record of such IP, and, should there be a case in the future, where a pharmaceutical company wants to commercialise such knowledge, it can be proven in a court of law that the intellectual property belongs to a holder of indigenous knowledge. For instance, in their work, a new record was documented for the use of *Aloe dichotoma* to treat cancer and asthma by Jan Baadjies. Any commercialisation of such Indigenous Knowledge, without rightful acknowledgement and financial compensation to the holder of Indigenous Knowledge, can now be addressed, as there is a published record, which will ease possible litigation. These researchers practised respect for the rich botanical knowledge of participants, and the fact that this knowledge was recorded was valued by the participants. Jan Baadjies was invited to hand over copies of the research to the local library.
Honesty — avoiding academic language and jargon that hinders clear communication	These researchers used consent letters and instruments that show a good knowledge of the culture and tradition of the region. For instance, all the participants are known by nicknames (called 'klein naam' by the participants), and such terminology was utilised in the instruments. The simplicity of the instruments, and how the researchers did the research in the backyards of the participants, provided a special bond between them. Also, the participants were involved as co-researchers, and acknowledged as such, in the publications.

Table 11.2 continues on the next page →

TABLE 11.2 (Continues...): The research of De Beer and Van Wyk (2011) through the lens of the San Code of Research Ethics.

Tenets of San Code of Research Ethics	Compliance by De Beer and Van Wyk (2012)
Justice and fairness — disclosure on how research benefits the entire community	These researchers have provided the names of the holders of indigenous knowledge (with the necessary consent) in all publications (in some publications, photographs of the holders of indigenous knowledge are also included [De Beer 2012:81]). This recognition did wonders for the self-esteem of the participants. Copies of the publications were provided to the Calvinia Library, and research participants enjoyed the recognition that they received from the local community. At least one participant in this research (Jan Baadjies) was so empowered by his participation in the research that he started to offer guided walks to tourists in the community, teaching them about the ethnobotany of the region.
Care — caring for community and the environment	During their research, Ben-Erik van Wyk — as a seasoned botanist — provided suggestions to local holders of indigenous knowledge on more sustainable harvesting practices for some of the medicinal plants. Furthermore, the researchers later (2017) started an intervention in the Namaqua district, providing professional development programmes for science teachers, to preserve this rich indigenous knowledge. This is a direct consequence of the original ethnobotanical research and is discussed in chapters 2 and 5 of this book.
Process	When this research was conducted (2009–2012), the San Code of Research did not exist.

Source: De Beer and Van Wyk (2012).
IP, Intellectual Property.

Conclusion

Our knowledge has been taken by clever people.
Vaalbooi (n.d.)

Petrus Vaalbooi, Steenkamp's colleague, elaborates on the lack of respect and the cultural imperialist knowledge theft endemic in former colonialised places. His statement makes visible the knowledge hierarchy that suppresses IK and erases indigenous rights (Kaya & Seleti 2013:30). Based on principles of mutuality and reciprocity, Vaalbooi advocates for mutual respect and collective action for the benefit of future generations. The San Code of Research Ethics can be instructive to the NWU PRRE and probably for other South African universities as well. Alignment advances the necessary action of decolonising higher education to make it mutually beneficial to all communities of people.

In this chapter, we tried to contribute an African perspective to the global discourse on institutional research ethics. Postcolonial indigenous thought, and elements of discourse analysis, offers new perspectives on decolonising institutional research ethics policy. By focussing on ethics policy, we potentially shifted the discourse towards a more collaborative relationship between IK communities and institutions of higher learning. Our purpose was to focus on issues of power that are endemic to institutional ethics research policy decision-making. The process of creating institutional policy is not as transparent as policy production in other areas of society; however, such grave consequences of misappropriation reproduce social ills. The process should be transparent and include the voices of IK holders in the decision-making process. This chapter is also purposed to advance the discussion of decolonisation of African universities by contextualising research ethics policy and research to meet the needs of indigenous African populations. The institutional reliance on European, Western and foreign influences in research ethics policy may reveal an internalised inferiority complex of African scholars to epitomise knowledge from other (European, Western and foreign) places at the expense of the wealth of local knowledges.

As academic researchers, we understand our role as knowledge brokers in the research process (Foucault 1977:27). Textual analysis is an interpretation that relies on our understanding and judgement. Understanding the text requires understanding the author's intentions and judging the relationship between their intentions and their claims (Fairclough 2003:26). This interpretation judged the alignment between the institutional intentions and social context in which research activities occur. We acknowledge the consequences of our analysis; we include what we know, but it is also limited by what we do not know. This analysis by no means exhausts all knowledge and understanding of the two texts examined in this chapter. We navigate the space between IK communities and the academy. How we do that determines whether the legacy of colonialism continues or ceases. When we do research with these communities, we are responsible for knowing their rights and redefining research in ways that mutually benefit indigenous communities and the academy. The knowledge in the academy should serve the needs of the people instead of building knowledge for knowledge's sake. As stated in the San Code, 'we do not know our sensitivities'. The vulnerability of the San is instructive to institutional ethics policy; we can learn from each other.

Summary

Historically, IK in South Africa has been suppressed, scantly entering institutions of higher education. Recent social and political shifts recognise IK as viable knowledge systems that parallel Western knowledge. Indigenous knowledge emanates from a relational ontology where research and ethics are embedded in the culture, language and worldview of the IK holders. In contrast, a Western perspective supports objective, universal truths often disconnected from local contexts and people. This chapter discusses how these philosophical perspectives are negotiated in an institutional research ethics policy. The authors specifically examine the alignment between San IK research ethics and an institutional research ethics policy. This chapter is situated in a postcolonial indigenous framework that critiques Western universality in research ethics. Following an outline of the problem, the authors provide a critical analysis of the PRRE at NWU. The analysis considers the social-historical context of knowledge and power in South Africa, which influences research ethics. The authors examine the alignment between the institutional policy and IK research ethics, as outlined in the San Code of Research Ethics. Areas of alignment and misalignment are identified and discussed. The chapter concludes with recommendations for policy alignment. In the current climate of decolonisation, this chapter has implications for making institutional research policy ethical for IK research.

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In light of serious efforts to integrate indigenous knowledge (IK) into the national curriculum, this book reflects on the value that IK has to offer. The question is how do you bring IK into the curriculum? Answering this question forms the core of this scholarly book. One of the book's strengths is showing not only what indigenous people know of plants, animals and the relationship of human life to the physical environment, but also how IK has different approaches to looking at problem solving and decision making. We have much to learn from other cultures and this book describes how the San, who have successfully lived in Southern Africa for thousands of years, have learned from nature, faced problems, tested solutions, and shared ideas. This book provides strategies for merging IK into the nation's classrooms. The book explores the importance of developing a code of ethics for research done cooperatively by researchers and subjects.

George Dawson, Science Education Program, School of Teacher Education, College of Education, Florida State University, Tallahassee, FL, United States of America

The content of this collected work is relevant and very suitable for the nature of the discourses currently afloat in Institutions of Higher Learning. The book is theoretically well grounded, which is a fundamental requirement for its uptake by the intended academic audiences. Good scholarly work is displayed, and it is trustworthy and credible. The fresh angle here is using a lens of self-directed learning to explore and interrogate the decolonisation project.

Prof. Annemarie Hattingh, School of Education, Faculty of Humanities, University of Cape Town, Cape Town, South Africa

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