A Two-Eyed Seeing Context-based Approach for Incorporating Indigenous Knowledge into School Science Teaching

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Abstract

This paper is about using a 'Two-Eyed Seeing' approach as the process of co-learning for incorporating elements of indigenous knowledge into school science teaching. Two groups of 150 Form 3 integrated science learners drawn from six high schools in Mutare, Zimbabwe, comprised the study sample. One group of learners, the control group, was taught the concepts of forces in structures in the traditional way. The other, the experimental group, was prepared using a context-based Two-Eyed Seeing framework. A mixed-method but primarily quantitative research approach involving a pre-test–post-test control group quasi-experimental design was used to investigate the achievement differences between the two groups of learners. A content knowledge test (CKT) and a paper-and-pencil theory of practical skills test (PST) were administered to the two groups prior to and following instruction. The analysis showed that the experimental group produced significantly better results than the group following the traditional approach (CKT, $F = 131.593$, $p < 0.0001$; PST, $F = 116.350$, $p < 0.0001$). Focus group interviews indicated that achievement differences were strongly linked to the pairing of indigenous knowledge and technology as relevant pedagogical contexts with the school science content knowledge, which resulted in intrinsic motivation for meaningful learning. The qualitative data complemented the quantitative data.

Keywords: Two-Eyed Seeing, indigenous knowledge, context-based science teaching, learning cycle

Introduction

Zimbabwe's current 'O' level (Forms 3–4) integrated science curriculum provides for the inclusion of indigenous knowledge (IK) into its teaching. However, few science teachers if any, have developed the heuristics for doing so (Mpofu, 2016). In recent times, the 'O' level integrated science chief examiners' reports have shown that the candidates have performed consistently poorly over five years in the science concept of forces that operate in physical structures (ZIMSEC, 2011). The reports suggest that IK and technologies that reflect the culture and geography of the community should be used to facilitate a better understanding of science concepts which prove difficult to candidates.

There are legitimate reasons for incorporating indigenous or community-based resources into school science teaching, and not least is the potential to increase the socio-cultural relevance of science education and to enrich instructional practice for improved motivation and performance (Gilbert et al., 2011). Indigenous knowledge is neither a uniform concept across all indigenous peoples, nor is it the exclusive preserve of the indigenous, rather it is a diverse body of knowledge spread throughout different peoples in many layers. For that reason, there is a multitude of indigenous epistemologies (Onwu & Mosimege, 2004). It is so much 'a part of the clan, band, or community, or even the individual that it cannot be separated from the bearer to be codified into a definition' (Battiste & Henderson, 2000, pp. 35–36). Indigenous knowledge is here understood and defined as an existing body of knowledge 'commonly known within a community, or a people that covers technologies and practices that have been developed and are still used by local people' (Onwu & Mosimege, 2004, p. 2) over generations of inhabiting a particular ecosystem (Kibirige & Van Rooyen, 2007), with the result that such knowledge allows the 'peoples/communities to develop a perfect understanding of the relationship of their communities to their surrounding natural and social environments' (Dei & Asgharzadeh, 2006, p. 54). This definition embraces both testable and non-testable metaphysical phenomena, and so not all IK may be utilised with school science.

As Taylor and Cameron (2016) have posited, there are elements on which both IK systems and Western or modern science may be viewed as intersecting domains, with overlaps and discrepancies. As knowledge domains, the two agree on both declarative knowledge, for giving factual information (i.e. 'knowing it'), and procedural knowledge, for providing evidence of practical knowledge ('knowing how'). The differences lie in the ways of knowing. The central concern of this paper is not about any competing perspectives between IK and scientific ways of knowing, rather it is about an understanding of how science and indigenous technologies/practices can co-exist where they share commonalities and be beneficially used to facilitate relevant science teaching for more meaningful learning.

This study is about incorporating IK contexts in teaching concepts of forces in physical structures for improved learning in Zimbabwe's 'O' level syllabus (ZIMSEC, 2010). We define 'context' here as some familiar focal event used by a community of practice that draws the attention of learners while remaining embedded in its cultural setting (Duranti & Goodwin, 1992). Thus the use of indigenous technologies as contexts signifies a context-based approach to science teaching for science concept development. The term context-based education, as defined, relates to using instructional activities and learning materials that mirror real-life experiences and environments of the learner for improved performance (Taylor & Mulhall, 2001). A more recent review would suggest that context-based courses are increasingly being used to address some of the significant challenges that science education currently faces (Gilbert et al., 2011). Convincing evidence has been presented that shows that context-based teaching approaches improve learners' attitude and engagement with learning science, but that their effect on learner achievement is contradictory (Bennett et al., 2007). The absence of effects on learning outcomes can be caused by several factors, including those related to the model used to develop and implement the material (Gilbert, 2006) and a weak relationship between contexts and relevant concepts in the perception of learners and teachers (Gilbert et al., 2011), among other things. This situation underlines the need to improve context-based units and approaches for concept development and transfer.

With this in mind, this preliminary study explored the use of a Two-Eyed Seeing (TES) model of co-learning proposed by Hatcher et al. (2009) to incorporate IK contexts in teaching concepts of forces for improved conceptual understanding. Our interest was in determining whether this version of a TES context-based approach for including IK in science teaching would result in significantly improved learner achievement.

The study addressed the following questions:

1. Would there be any significant differences between learners exposed to the TES context-based teaching approach and those exposed to the traditional teaching in their achievement of some concepts of forces in physical structures?
2. What are the teachers' and the learners' views of the approaches used to teach the concepts of forces?

Background

Teachers face multiple challenges, in incorporating IK into school science teaching for more meaningful learning. These challenges stem from both ideological and practical considerations (Dube & Lubben, 2011 ; Naidoo & Vithal, 2014; Nhalevilo & Ogunniyi, 2014; Seehawer, 2018) and therefore require heuristics/frameworks for including IK in a legitimate and useful way in science teaching.

In order to resolve the ideological challenges, several scholars (Cohen et al., 2011; Loubser, 2013; Webb, 2011) have proposed possible frameworks. Loubser's (2013) pre-scientific and scientific frameworks on how knowledge develops and the Popperian requirements of demarcating bad from good theories (Cohen et al., 2011) make it theoretically possible to map where different knowledge claims fit or could cohere with one another. Even though Webb's (2011) framework of combining both Loubser's and Popper's thinking makes it possible to map where different knowledge claims should lie, it does not necessarily provide the teachers with the specific heuristics for identifying IK that is compatible with the school science curriculum. More recently, Zinyeka et al. (2016) have proposed a pragmatic truth-based epistemological framework to support teachers to make decisions on how they can include specific elements of IK in science lessons. However, it is difficult to see how this framework alone can assist science teachers in handling characteristic features of IK, which may be partially true or correct but can only advance IK explanations (Mueller & Tippins, 2010).

Some other scholars (Mueller & Tippins, 2010; Van Eijck & Roth, 2007) have offered the cultural–historical activity theory (CHAT). The theory's central premise is that knowledge is context based, and is always about something real. Van Eijck and Roth (2007) used CHAT to analyse a typical activity system to see what aspects of IK to include or not include in science teaching. The study's main findings were that the CHAT framework importantly recognises that both scientific knowledge and IK are always simultaneously available and also that aspects of IK explanations that have equivalence with scientific explanation could be included in science teaching. Based on these findings, they questioned the concept of absolute epistemological truth as a framework for the calibration of the status of IK and science. Mueller and Tippins (2010) in their response to Van Eijck and Roth's (2007) objection, proposed the theory of the epistemology of partial truths (also known as relational epistemology) as a pragmatic framework for identifying aspects of IK practices with overlapping strands in school science teaching. The theory refers to a 'mode of seeing the world in partial truths, not yet complete, evolving relationally' (p. 996). The authors argue that science and IK are both partial truths and interconnected expressions of useful knowledge. They, therefore recommend that knowledge claims should be evaluated in terms of their usefulness and their ability to facilitate understanding rather than being true *per se*. Hence, the pragmatic approach we adopted in this study is one of complementarity and the usefulness of incorporating local knowledge and practices as IK contexts that are likely to arouse interest and enhance motivation. To this end, the IK-science inclusion framework that we used for investigating learner's developing conceptual understanding of the concept of forces was that of Hatcher et al.'s (2009) TES model.

Conceptual Framework

The conceptual framework of this study derives in part from the TES lens of Hatcher et al.'s (2009) model. Two-Eyed Seeing is about 'learning to see from one eye with the strengths of indigenous-ways of knowing and from the other eye with the strengths of Western ways of knowing and learning to use both of these eyes together' for the benefit of all (p. 146). The authors see TES as a gift of multiple perspectives that enables other transdisciplinary and transcultural work. Although not previously considered among the traditional frameworks for research in science education, in recent times the TES lens has offered a new perspective for reconciling the useful methods of science with elements of IK and practices (Abu et al., 2019; Peltier, 2018). Thus, the scope of relevance for TES is potentially broad, and its uptake in this study places it in the context of emerging theory for transcultural research in science education (cf. Bartlett et al., 2012).

Continuing research in this area of the principle of co-learning for mutual benefit has led Hatcher et al. (2009) and Bartlett et al. (2012) to identify four constituent elements for advancing transcultural research. The first element entails a co-learning philosophy, involving situations within which mental encounters with contexts are located or situated. In this study, it involves teaching science concepts alongside the identified indigenous technologies and practices. The second element is about culture and community, which calls for the use of familiar local technologies and practices of the community as authentic contexts. In this study, we use IK contexts that are familiar and accessible to both boys and girls, and likely to stimulate interest and curiosity for teaching the concepts. The third element concerns the need for a psychologically safe and conducive learning environment. Here, the focus is on the behavioural classroom environment, within which the context is interrogated with specific attention to key concepts that enable discussion and activities among learners. We used a cooperative learning structure with small groups to provide for learners' active contributions to their own learning as well as that of others (Hatcher et al., 2009). The fourth element is about the use of pedagogical strategies that resonate with the way cultural knowledge is sometimes transmitted in communities. In this study, we used storylines to introduce the IK contexts with accompanying questions for interrogating the context relating to the science concepts taught. We used a learning sequence based on the four elements of the TES model that in principle provides for learners to negotiate the process of learning themselves through reflecting on the adequacy of their existing knowledge and forces them to argue about, discuss and test their preconceptions.

These four elements of the TES model are amenable to a context-based teaching approach. In practice, it involves a sequence of lesson activities for learners to engage in and comprises, first, the introduction of a familiar context, followed by learner interrogation of the context, identification of science concepts possibly explaining the context, teaching of science concepts and application of science concepts to a new familiar context, in that order (Bennett & Lubben, 2006). Gilbert (2006) has synthesised four models for developing context-based courses depending on the role or functions of the 'contexts' that explicitly underpin the learning materials. In this study, our interest was in using IK contexts representing real-life issues occurring in the community setting as the starting point or rationale for teaching the concepts. According to Gilbert (2006, p. 969), this TES context-based approach is referred to as the 'context as social circumstance' model and is based on situated learning and activity theory. Situated learning assumes that it is the nature of the physical, social and psychological environment of the learners that influences the quality of learning (Greeno, 1998). Furthermore, it assumes that the environment is at its most effective when the teacher and learners are engaged in mutually supportive interaction within a 'community of practice' (Gilbert et al., 2011, p. 821). Learning in this approach is primarily activity oriented, involving genuine inquiry and active learner participation in which context shapes the meaning of the content and vice versa.

Following the four educational elements of the TES model, we posited that this version of a context-based teaching approach would be further enhanced by a five-phase TES context-based learning sequence, to situate active learning for building conceptual understanding as follows:

1. introduction of IK context;
2. interrogation of the context;
3. concept introduction;
4. linkage of concepts and context;
5. assessment of learning—application of concepts to a new familiar context.

The example below illustrates the five-phase learning cycle for teaching the concept of a beam using local technology as a context.

Phase 1: Introduction of IK Practice as a Context

The following storyline describes a rural community technology, a loading platform, whose function and construction are related to understanding the concept of forces on a beam. It is a familiar and local structure that is meant to orient the learner, arouse interest and stimulate the 'need to know'.

Storyline

Mr Gara, the local farmer, has recently built a wooden structure ('Dara' in Shona) to store some of his farm harvest (Figure 1). The structure is made from specially dried and stripped logs of the 'muwanga' tree. Some of the long vertical logs which are placed far apart and fixed in deep holes in the ground are used to support the platform. These vertical logs are held together by four horizontal logs forming a hollow rectangular shape above the ground. The loading platform consists of round logs, which are packed tightly to each other in a horizontal and parallel position. The rectangular base supports them. Mr Gara has other loading structures for storing the bags of harvested crops depending on their size and weight.

Figure 1. Loading platform

Phase 2: Interrogation of the Indigenous Knowledge Practice

This phase evokes the learners' 'need to know' through relevant questions. They work cooperatively in small groups (four or five learners) to try to answer the questions about the local practice. They discuss among themselves and engage with the teacher in a community of knowledge sharing. In the process, the teacher can diagnose any misconceptions to be subsequently used as a teaching point.

1. Name any other structure in your community used as a loading platform.
2. Why did Mr Gara use specially dried and stripped 'muwanga' logs to build the wooden structure?
3. (a) What force(s) can act on the loading platform when it is not loaded with maize, for example? At what point does this force act?
    1. What forces can act on it when (i) it is loaded with maize and (ii) more load is added, and it starts to bend?
    2. Where are the forces acting when the beam starts to bend?
4. Why are the shape and treatment of the logs important to build the loading platform?
5. Which part of the structure is a beam?

Phase 3: Introduction of the Science Content

The third phase involves the teacher using learners' explanations and questions to present relevant concepts of forces in beams. The focus is on preparing learners through their 'talk' to develop a coherent use of concept-specific scientific language that will enable them to answer the questions on the loading platform and beams. Different themes of the topic are re-visited again and again using a variety of structured learning and practical activities to help the learner to develop mental maps for enhancing the links between questions on local practice and information in the textbook.

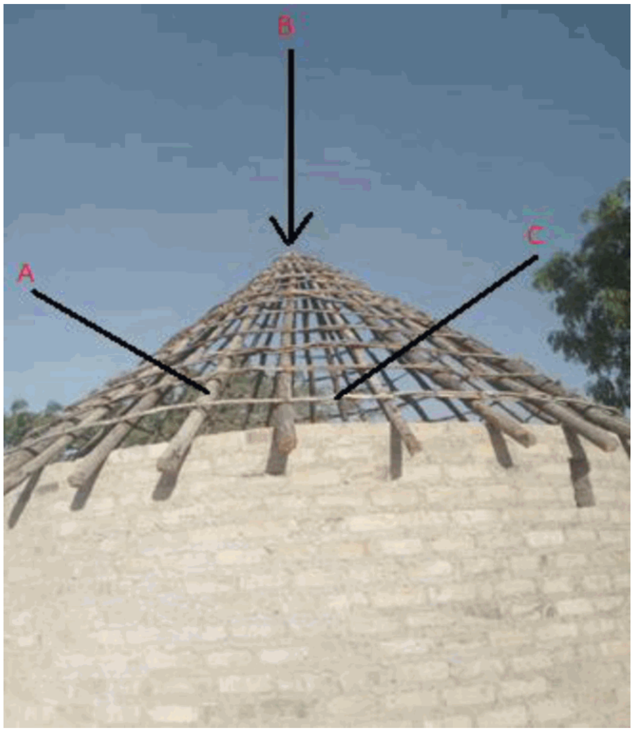
Phase 4: Linkage of Science Content and Indigenous Knowledge Practices

In the fourth phase, the learners work in small groups to re-visit the questions they tried to answer in phase 2. They focus on their initial answers to determine why they gave those responses. The questions below guide them. A cooperative learning structure is in place and provides for a non-competitive learning environment. The aim is to enable learners to build coherent 'mental maps' and conceptual understanding of the forces inherent in a fully loaded beam and to apply the knowledge in other contexts.

- Do you think your initial answers and explanations in phase 2 are correct or wrong?
- If you think they are wrong, why have you decided to change them and what are the correct answers?
- If you think your initial answers in phase 2 were correct, explain why.
- Do the lessons on the beam clarify the types of force that can act on the loading platform?

Phase 5: Assessment of Learning

The final assessment phase required the learners to apply the concepts in a new context.



1. What forces do the parts labelled A and C experience when the dry grass (thatch) is attached to the truss?
2. What is the force labelled B?
3. Explain why the roofs of most round huts in your area are conical in shape?

Methodology

Research Design

In this study, we used a mixed-method research approach QUAN/Qual (Creswell, 2014) in which the primary data were quantitative. A non-equivalent pre-test–post-test control group quasi-experimental design was used to investigate the achievement differences if any, between the learners taught using the TES and those taught in the traditional way. The qualitative data were used to gain some insight into learners' and teachers' perceptions of the respective approaches used to teach the science concepts.

Data Collection

Participants

For the investigation, we used a sample of 150 Form 3 learner participants and their six teachers, drawn from six secondary schools in the Mutare central circuit. The schools were selected through systematic stratified sampling from the population of schools in the circuit. The selected schools met the following criteria of offering integrated science as the only science subject, being under-resourced and having below-average performance in the O-level results. All of the six schools had science teachers qualified to teach at the secondary school level with a minimum qualification of a Diploma in Education. Eighty learners from three schools of intact classes and 70 learners from three schools of another set of intact classes comprised the experimental and control groups, respectively. The three teachers for the experimental group were trained in the TES approach and rated by a panel of judges. Both the experimental and control group teachers taught their regular class groups for six weeks. The lessons of both groups were observed periodically to assure consistency. Following the post-tests, focus group discussions were held with the two groups of learners as sources for the qualitative data. One-on-one interviews were held with their teachers to elicit their views as well.

Instruments

The two test instruments, the content knowledge test (CKT) and a paper-and-pencil theory of practical skills test (TPST), were developed and pilot-tested for content validity and reliability. Using the test–retest reliability technique, the Pearson correlation coefficient index (Gall et al., 2007) for the CKT was $r = 0.94$ and the PST was $r = 0.81$. The CKT and TPST instruments were administered to the consenting Form 3 learners in that order as the pre- and post-tests.

Example of an item in the Content knowledge test

Item: The photograph below shows some branches of the peach tree bending downwards.

1. Identify the types of force acting on the parts labelled A and B.
2. Name any one physical structure or material in your community that you know experiences the forces you identified in (1).

We used tape-recorded focus group discussions with learners and individual interviews with teachers to collect qualitative data. The transcribed and coded protocols were assigned to pre-determined themes. For the learner data, the focus was on (a) their perception and experience of the particular teaching approach used, (b) the relevance to their lives in studying the topic and (c) their interest in school science.

Teachers' responses were categorised along the interview themes, namely, their views on (a) the teaching approach they used, (b) the post-test performance of their learners and (c) learners' disposition towards the study of integrated science.

Results

Quantitative Data

The quantitative data were analysed using analysis of variance (ANOVA) and analysis of covariance (ANCOVA) to test the null hypothesis that there would be no significant differences between the achievement of learners taught using the TES approach and those taught through the traditional way of teaching. Table 1 summarises the pre-test and post-test inferential statistical results of the assessed learning outcomes of both the experimental and control groups.

Table 1. Pre-test and post-test descriptive and inferential statistics for TPST and CKT learning outcomes

Test	Treatment	Pre-test					Post-test				
		N	Mean	SD	*F*-value	*p*-Value	*N*	Mean	SD	*F*-value	*p*-Value
CKT	E	80	17.7	6.9	3.709	0.056	80	50.4	11.5	131.59	<0.0001
	C	70	15.7	5.3			70	30.5	8.8		
	Difference		1.96	1.6				19.9	2.7		
TPST	E	80	9.5	5.9	2.328	0.129	80	55.4	11.8	116.35	<0.0001
	C	70	10.8	7.3			70	32.8	14.5		
	Difference		−1.3	−1.4				22.6	−2.7		

CKT, Content knowledge test; TPST, theory of practical skills test; E, experimental group; C, control group.

The results from the ANOVA of the pre-test mean scores showed no significant differences in the cognate abilities of the two groups on the CKT and PST assessment tests before the intervention (Table 1). Following the intervention, the ANCOVA of the post-test mean scores showed that the experimental group performed significantly better than the control group in the CKT ($F = 131.593$; $p < 0.0001$) and PST ($F = 116.350$ $p < 0.0001$) tests. The null hypothesis was therefore rejected.

Qualitative Data

Experimental Group

The analysed data from the experimental group revealed that there were themes common to both the learners and their teachers in their views on using the TES approach. A summary of the themes identified as evidenced in the respective representative voices of learners and teachers respectively follows.

Themes identified: (a) more learner motivation and engagement; (b) linking of local practices with the science teaching (first *TES element*); (c) the use of familiar technology (*second TES element*); (d) psychologically safe and conducive environment (*third TES element*); and (e) the use of storylines and questions (fourth TES element).

> *Learner E1*: Our teacher used things which we know in our community. He allowed us to talk among ourselves and to try to find answers to the questions in the worksheet. Learning some of the things in our mother tongue helped us to want to know more about the things we do in the community and how they can help us to learn science well.

Here, we note the linking of local practices with science teaching in the use of familiar technologies and storylines with accompanying questions within a psychologically safe and conducive classroom environment; that enabled the interrogation of ideas to readily take place among the learners more so in their home language. All of which seemed to motivate the learners to want to 'learn science well', i.e. with meaning and understanding.

> *Learner E2:* I learned science in a different way from what we usually do in class. I think that I can remember some of the lessons on 'mawariro' (beams) for a long time … in the experiments that we did, our teacher allowed us to talk among ourselves and answer the worksheets on our own.

Here, there is evidence of a psychologically safe classroom environment that enabled learner's contributions to their learning as well as to others.

> *Teacher E1*: Learners were very interested in the lessons since the teaching materials included things from the local community. Moreover, to realise that they could be used to teach a topic such as force motivated them. Seeing the use of local technology was important to them.

> *Teacher E2:* The use of descriptive accounts of familiar things (storylines) to introduce the lessons made the learners curious and rather attentive. The learners participated actively and very well, especially in phases two (discussion among themselves) and four (reflections on their discussions and answers) of the teaching approach. They liked the idea of linking the local practices to their school science.

With both teachers we note the improved learner performance being attributed to all the four elements of the TES approach: the use of familiar local technologies in science teaching and as storylines with accompanying questions to introduce and teach the science lessons, a psychologically safe and classroom environment that enabled discussions and the interrogation of the IK contexts, which resulted in more learner motivation and engagement with the science concepts.

Control group

The learners and teachers from the control group identified themes that resonated with (a) a lack of availability of laboratory facilities, (b) a lack of practical activities and (c) low motivation.

The following comments represent those views:

> *Learner C13*: Our teacher did not do any activities with us … , he used the textbook to teach us, so we studied through reading and memorising the textbook.

> *Learner C17*: Our teacher tries hard to tell us everything, but we always find the stuff difficult to understand. Sometimes our teacher was rushing and not giving us much time.

> *Teacher* C*5*: I mostly used the question and answer method because my school does not have a laboratory and equipment. Trying to improvise takes too much time and makes me be behind the syllabus schedule.

Teacher C4: My learners struggled to complete the classwork correctly especially on questions to do with types of forces experienced in the different members of a structure when it is loaded … because of the lack of practical work.

Discussion of Results

The learners using the TES context-based teaching model performed significantly better than those taught using the traditional teaching approach in the achievement of the concepts of forces in structures. The findings of this study are consistent with studies that have used the TES co-learning approach to (a) bridge Western science and IK perspectives for enhancing the understanding of social-ecological change (Abu et al., 2019), (b) integrate indigenous and mainstream knowledge and ways of knowing (Bartlett et al., 2012) and (c) apply the TES approach to participatory action research methodologies (Peltier, 2018). Other studies that meet the criteria of 'context as the social circumstances', just like the TES context-based approach used here, have demonstrated the efficacy of the context-based learning cycle model in science content achievement (Kazeni & Onwu, 2013) and the successful implementation of a culturally based curriculum (Gilbert et al., 2011).

The differences in the achievement between the experimental and control groups were strongly associated with the pairing of familiar indigenous technologies and school science content knowledge as a process of co-learning that seemed to result in increased learner motivation and enhanced conceptual understanding.

The qualitative data gives more insight into rationalising the performance differences between the two groups of learners. Comparing the themes arising from the post-intervention focus group interviews of both groups of learners about their perception and experience of the particular teaching approach used, the experimental group on the one hand claimed to be highly motivated and favoured the TES model. On the other hand the control group was less motivated and suggested more practical activities in their traditional classroom lessons. The experimental group, for instance, appreciated the TES approach, citing the use of familiar local technologies in the teaching of science within a classroom environment that was psychologically safe and conducive to situated learning. In particular, such learning was appreciated in the learners' use of their mother tongue to reflect on their thinking with close attention to the specific concepts involved. The TES model reiterates the need for a learning environment that provides for learners' active attention and engagement in contributing to their own learning as well as to that of others (Hatcher et al., 2009). In that respect it is instructive that learners E1, and teachers TE1 and TE2, all mention learners' motivation to 'learn science well' as a result of there being an environment where the learners and their teachers feel themselves mutually engaged for improved quality of learning. Thus, the differences in achievement could arguably be attributable among other things, to the experimental group having a richer motivational classroom experience than the control group.

The assumption that learners actively construct their own knowledge is the best way forward for rationalising the performance differences within the TES framework. From a constructivist perspective, it is assumed that learners only effectively learn what motivates or is of interest to them and that learning is mediated by familiarity with context or what is already known (Ogborn, 1997). The results show that at least three of the four TES elements, namely linking of local practices to the teaching of science, the use of familiar technology and the use of storylines with related questions, were mentioned by the learners and teachers in discussing the efficacy of the approach in improving learners' conceptual understanding.

Given the four elements of the TES approach, and building on the qualitative data, we surmise that the TES context-based learning cycle is at the interface of concept development and teaching, where learners are motivated to try to reach an understanding of the science concepts being taught by actively engaging with matching relevant pieces of knowledge from both science and the local technologies for improved conceptual understanding. The talk (in the home language) associated with interrogating the local technology in a cooperative learning environment is likely to enable the broader language register and explicit understanding of the science principles embedded in the local practice (cf. Gilbert et al., 2011). Altogether a co-learning philosophy of the TES model, which advocates culturally responsive science teaching (including learner's cultural background) that provides for active learner participation in context-based situated science learning, is likely to increase motivation and hence facilitate improved learning.

For the control group, there is no doubt that alienation of learners from science may be largely due to the way it is taught, specifically in meeting the interests and aspirations of the learners. Practical activity-based learning in school science is a *sine qua non* for increasing motivation and in turn developing conceptual understanding. The lack of any practical activities led to low motivation. This study benefits the science teacher in providing the heuristics or framework for translating appropriate local technologies/practices and school science into classroom plans and activities.

Conclusion

In conclusion, the TES approach and the logic of its four elements for incorporating IK into science teaching is shown to be statistically significant in improving learner achievement in the concept of forces. Thus this TES version of the context-based teaching approach is seen in the eyes of the learner and the teacher as something motivating and meaningful. With TES as an approach, the science teacher familiar with both knowledge systems can uniquely combine the two in various ways to promote meaningful learning.

Disclosure Statement

No potential conflict of interest was reported by the authors.

References

Abu, R., Reed, M. G., & Jardine, T. D. (2019). Using two-eyed seeing to bridge Western science and indigenous knowledge systems and understand long-term change in the Saskatchewan River Delta, Canada. *International Journal of Water Resources Development*, 1–19. https://doi.org/10.1080/07900627.2018.155805

Bartlett, C., Marshall, M., & Marshall, A. (2012). Two-eyed seeing and other lessons learned within a co-learning journey of bringing together indigenous and mainstream knowledges and ways of knowing. *Journal of Environmental Studies and Sciences*, *2*(4), 331–340. https://doi.org/10.1007/s13412-012-0086-8

Battiste, M., & Henderson, J. Y. (2000). *Protecting indigenous knowledge and heritage*. Purich Publishing.

Bennett, J., & Lubben, F. (2006). Context-based Chemistry: The Salters approach. *International Journal of Science Education*, *28*(9), 999–1015. https://doi.org/10.1080/09500690600702496

Bennett, J., Lubben, F., & Hogarth, S. (2007). Bringing science to life: A synthesis of the research evidence on the effects of context-based and STS approaches to science teaching. *Science Education*, *91*(3), 347–370. https://doi.org/10.1002/sce.20186

Cohen, L., Manion, L., & Morrison, K. (2011). *Research methods in education* (7th ed). Routledge.

Creswell, J. W. (2014). *Research design* (4th ed). Sage.

Dei, G. J. S., & Asgharzadeh, A. (2006). Indigenous knowledge and globalization: An African perspective. In A. A. P. Abdi, P. Korbla, & G. J. S. Dei (Eds.), *African education and globalization: Critical perspectives* (pp. 53–78). Lexington.

Dube, T., & Lubben, F. (2011). Swazi teachers' views on the use of cultural knowledge for integrating education for sustainable development into science teaching. *African Journal of Research in Mathematics, Science and Technology Education*, *15*(3), 68–83. https://doi.org/10.1080/10288457.2011.10740719

Duranti, A., & Goodwin, C. (Eds.). (1992). *Rethinking context: Language as an interactive phenomenon*. Cambridge University Press.

Gall, M., Gall J., & Borg, W. R. (2007). *Educational research: An introduction* (8th ed.). Pearson.

Gilbert, J. K. (2006). On the nature of ‘context’ in chemical education. *International Journal of Science Education*, *28*(9), 957–976. https://doi.org/10.1080/09500690600702470

Gilbert, J. K., Bulte, A. M. W., & Pilot, A. (2011). Concept development and transfer in context-based science education. *International Journal of Science Education*, *33*(6), 817–837. https://doi.org/10.1080/09500693.2010.493185

Greeno, J. (1998). The situativity of knowing, learning and research. *American Psychologist*, *53*(1), 5–26. https://doi.org/10.1037/0003-066X.53.1.5

Hatcher, A., Bartlett, C., Marshall, A., & Marshall, M. (2009). Two-eyed seeing in the classroom environment: concepts, approaches, and challenges. *Canadian Journal of Science, Mathematics and Technology Education*, *9*(3), 141–153. https://doi.org/10.1080/14926150903118342

Kazeni, M., & Onwu, G. (2013). Comparative effectiveness of context-based and traditional approaches in teaching genetics: Student views and achievement. *African Journal of Research in Mathematics, Science and Technology Education*, *17*(1–2), 50–62. https://doi.org/10.1080/10288457.2013.826970

Kibirige, I., & Van Rooyen, H. (2007). Enriching science teaching through the inclusion of indigenous knowledge. In H. Van Rooyen (Ed.), *Teaching science in the OBE classroom* (pp. 235–247). MacMillan Press.

Loubser, A. (2013). Tracing some consensus regarding pre-scientific frameworks in philosophy of science. *Acta Academia*, *45*(2), 59–84.

Mpofu, V. (2016). *Possibilities of integrating indigenous knowledge into classroom science: The case of plant healing*. Unpublished doctoral thesis, University of the Witwatersrand, Johannesburg, South Africa.

Mueller, M. P., & Tippins, D. J. (2010). Van Eijck and Roth’s utilitarian science education: Why the recalibration of science and traditional ecological knowledge invokes multiple perspectives to protect science education from being exclusive. *Cultural Studies of Science Education*, *5*(4), 993–1007. https://doi.org/10.1007/s11422-009-9236-z

Naidoo, P. D., & Vithal, R. (2014). Teacher approaches to introducing indigenous knowledge in school science classrooms. *African Journal of Research in Mathematics, Science and Technology Education*, *18*(3), 253–263. https://doi.org/10.1080/10288457.2014.956407

Nhalevilo, E., & Ogunniyi, M. B. (2014). Reflections on the science and indigenous knowledge systems project: Voices of the participants. *South African Journal of Higher Education*, *28*(1), 221–235. https://doi.org/10.20853/28-1-319

Ogborn, J. (1997). Constructivist metaphors in science learning. *Science Education*, *6*(1–2), 121–133. https://doi.org/10.1023/A:1008642412858

Onwu, G., & Mosimege, M. (2004). Indigenous knowledge systems and science and technology education: A dialogue. *African Journal of Research in Mathematics, Science and Technology Education*, *8*(1), 1–12. https://doi.org/10.1080/10288457.2004.10740556

Peltier, C. (2018). An application of two-eyed seeing: Indigenous research methods with participatory action research. *International Journal of Qualitative Methods*, *17*(1), 1–12. https://doi.org/10.1177/1609406918812346

Seehawer, M. (2018). South African science teachers' strategies for integrating indigenous and Western knowledges in their classes: Practical lessons in decolonisation. *Educational Research for Social Change (ERSC)*, *7*(0), 91–110. ersc.nmmu.ac.za https://doi.org/10.17159/2221-4070/2018/v7i0a7

Taylor, D. L., & Cameron, A. (2016). Valuing IKS in successive South African physical sciences curricula. *African Journal of Research in Mathematics, Science and Technology Education*, *20*(1), 35–44. https://doi.org/10.1080/10288457.2016.1147800

Taylor, P., & Mulhall, A. (2001). Linking learning environments through agricultural experience—Enhancing the learning process in rural primary schools. *International Journal of Educational Development*, *21*(2), 135–148. https://doi.org/10.1016/S0738-0593(00)00036-5

Van Eijck, M., & Roth, W. M. (2007). Keeping the local local: Recalibrating the status of science and traditional ecological knowledge (TEK) in education. *Science Education*, *91*(6), 926–947. https://doi.org/10.1002/sce.20227

Webb, P. (2011). *Bridging the gap between Science Technology and Indigenous Knowledge Systems:Towards a shared epistemology*. Paper Presented at the Third International Conference on the Integration of Science and Indigenous Knowledge Systems: 'The melting pot: Science and IKS', p. 32–45. 25–28 October 2011, University of Western Cape, Cape Town. South Africa

ZIMSEC. (2010). *Zimbabwe general certificate of education*. Integrated Science 'O' level syllabus for Examination in June/Nov. 2011–2020. Zimbabwe.

ZIMSEC. (2011). *Examination reports*. www.zimsec.co.zw/A_REPORTS.html

Zinyeka, G., Onwu, G. O. M., & Braun, M. (2016). A truth-based epistemological framework for Supporting teachers in Integrating indigenous knowledge into science teaching. *African Journal of Research in Mathematics, Science and Technology Education*, *20*(3), 256–266. https://doi.org/10.1080/18117295.2016.1239963