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A Socio-cultural Model that Promotes Metacognition and Creativity: An Analysis of Intercultural Experiences within the Metacognitive Process in Physical Sciences Classrooms

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Abstract

This research analysed the cultural factor of metacognition within South African physical science classrooms, by conducting research on physical sciences classes within two KwaZulu-Natal districts. The data from the mixed methods design suggested that Indigenous pupils were not taught in their first language, cultural knowledge was not promoted effectively, and the teaching and learning environment favoured the teacher-centred approach which focussed on the examination. A model which drives metacognition and creativity, and promotes a growth mindset, whilst integrating real-world context and indigenous knowledge will resolve the conflict of the pupils' multiple world views and promote effective thinking skills.

Introduction

The Progress in International Reading Literacy Study (PIRLS) has found that eight out of 10 South African school children struggle to read by the age of ten (Mullis et al., 2023). The poor literacy results portend the uphill battle South African pupils must struggle with to gain the foundations to study science. Furthermore, research done by the Trends in International Mathematics and Science Study (TIMSS) found inequalities in science achievements in South Africa (Human Sciences Research Council, 2019). For example, the achievement gap between fee-paying and no-fee schools in Grade 9 showed 22% of pupils in no-fee schools and 66% in fee-paying schools having basic science knowledge and skills respectively (Human Sciences Research Council, 2019). Moreover, only 22% of the pupils spoke the test language at home (Human Sciences Research Council, 2019) which is a disadvantage to the majority of the pupils when it comes to interpreting the questions of the test. Socio-cultural factors such as race, language, the socioeconomic status of the home and school, and geographic location all factor in the inequality of attainment (Human Sciences Research Council, 2019). Immense and irrefutable research completed by numerous researchers over the last 40 years has pointed to the conclusion that improved metacognitive abilities lead to raised academic levels. However, work done Rajcoomar et al. (2022) showed that selected physical sciences classes had low attainment and poor metacognitive awareness. One may question whether there is a link between the socio-cultural factors and the effectiveness of fostering metacognition within the physical sciences and the poor attainment achieved by South African pupils.

The inter-connectedness of socio-cultural factors and metacognition is very broad and may be difficult to establish in the general sense. Therefore, this research views the impact of the culture of the studied population on the study of physics sciences in South Africa and views culture as a set of daily practices and the capacity to understand them in a real-world context. Within the studied populations it must be considered that there are complex ideas and intra-cultural variation. Culture outlines a set of expectations, where during the study of physical sciences the hypothesis aligns itself to predicted conclusions and answers. When the expectations align with the outcome, there is no need for the pupils to alter their interpretation of their worldview. When the expectations are not met there is increased uncertainty and reduced sense of achievement (Yan & Oyserman, 2018). The evaluation of the ease or difficulty of the processes which led to the outcome is metacognitive by nature. Metacognition is driven by these cultural experiences (Yan & Oyserman, 2018). The difficulties faced indicate a conflict between the perceived understanding, which may be culturally rooted, and the actual reality of the nature of the problem (Yan & Oyserman, 2018). The ability of the pupils to adapt from their cultural worldview to fit the context of the situation does cause conflict in interpretation and thought. Consequently, research question 1 (RQ1) was: "To what extent does the physical sciences curriculum promote the cultural worldview of the pupils?"

The context of physical sciences is promoted during the lesson in a language that may not be the same as the first language of the pupils (Human Sciences Research Council, 2019). Furthermore, when the pupil is out of the lesson, the world of physical sciences may not align with the world they experience. Subsequently, research question 2 (RQ2) was: "What were the pupils' attitudes towards science?". During the science lessons, there will be a struggle between indigenous culture and the culture of physical sciences. Aikenhead and Jegede (1999) describe those experiences as "cultural border-crossing". Hence, research question 3 (RQ3) was: "What are the views held by the sample population on "cultural border-crossing"?"

Literature Review

Collateral Learning Theory

Collateral learning theory explains how South African physical sciences pupils cope with contrasting worldviews facilitated by transcending cultural borders between their lived experience, indigenous culture, and the culture of science (Aikenhead & Jegede, 1999). Modern science is an enquiry process which reveals valid solutions that transcend cultural contexts and are free from political and cultural values (James, 2004). However, embedded political and cultural values in modern science impede progress and damage society (James, 2004).

Aikenhead and Jegede (1999) describe the lived experience of the South African physical sciences pupils and their science classroom experience as "cultural border-crossing". Using their metacognitive knowledge within their lessons, the pupils must ignore some of their cultural values. This requires the motivation and flexibility of the pupils to successfully experience the culture of science within the classroom. However, the problem lies outside of the classroom when the learner switches back to accepting their cultural beliefs. The learner is deprived of experiencing science in the real world due to switching from the culture of modern science and their lived culture during border-crossing.

The challenges of scientific language and the language of the pupils sometimes come into conflict in science (Aikenhead & Jegede, 1999; Sutherland, 2005). Scientific terminology may not be directly translated into many of the pupils' first language. Much of the scientific terminology comes from Western culture and the traditional understanding of the words is easier for Western pupils to comprehend, whereas many South African pupils may find it difficult to interpret. When the pupils' language and culture conflict with Western-based values embedded in the science curriculum, it may cause difficulty in advancing their metacognitive knowledge of science. Therefore, it is assumed the physical sciences have Western values embedded within their structure.

Impact of Culture on Metacognition

Success in learning is determined not only by genetics but also by the interaction between cognitive, motivational, and social-cultural factors (Helms-Lorenz & Jacobse, 2008; Thomas, 2002). Self-concept, motivation, economic factors, and family influences provide success in learning (Hartman & Glasgow, 2002; Helms-Lorenz & Jacobse, 2008). Metacognitive abilities and intelligence are also culturally driven. Metacognitive skills can positively influence pupils from different cultural backgrounds if their cultural background is taken into consideration during the teaching and learning process (Hacker & Bol, 2004; Helms-Lorenz & Jacobse 2008; Jost et al., 1998).

Research by Helms-Lorenz and Jacobse (2008) in the Netherlands on the metacognitive abilities of native Dutch and migrant pupils of similar intellectual ability levels concluded that native pupils tend to reach their true potential more quickly than migrant pupils do and tend to have slightly higher scores. This was due to the migrant pupils' lack of experience in the Dutch language, and cultural values, and inhibiting acculturation strategies (Helms-Lorenz & Jacobse, 2008). A specific difference in metacognitive skills was found across cultural groups. The second finding among the native group was a positive correlation between the high-ability pupils' results and their metacognitive skills, but this relationship was not transferable to migrant pupils of similar ability. The native pupils of the same ability levels as the migrant pupils had higher metacognitive abilities.

The research draws parallels in the context of the South African physical sciences pupils in a way that most pupils are not taught in their first language and how the cultural context conflicts with Western values embedded in the culture of modern science. The cultural conflict between the immigrant's culture and the culture in which the science is taught is similar to the situation South African physical sciences pupils experience in the classroom. Studies by Thomas (2002) suggest that the school and classroom environments can drive pupils to greater efforts to achieve academic success instead of valuing metacognition critical thinking.

Identity-based Motivation and the Promotion of Creativity in a Social Learning Environment

Identity-based motivation (IBM) is an interplay between culture, identity, and metacognition which explains when and in which situations pupils take action to achieve their goals (Oyserman, 2015). The action taken is the management of the cognitive resources of the learner through metacognitive processes. For example, during the lesson on equations of motion, the learner is given the following problem: " A rugby player kicks a rugby ball up above the ground with an initial vertical velocity of 80 $m.s^{-1}$. Calculate the maximum height the ball must reach for the left wing to reach the ball in 2 seconds." The metacognitive knowledge part of IBM comes into play to interpret the question, identify the possible equations, and select the correct equation to solve the problem (Schraw & Moshman, 1995).

Figure 1 below shows how the thought processes of metacognitive knowledge and regulation interact. Declarative skills are used to interpret the problem and find key information to solve the problem.

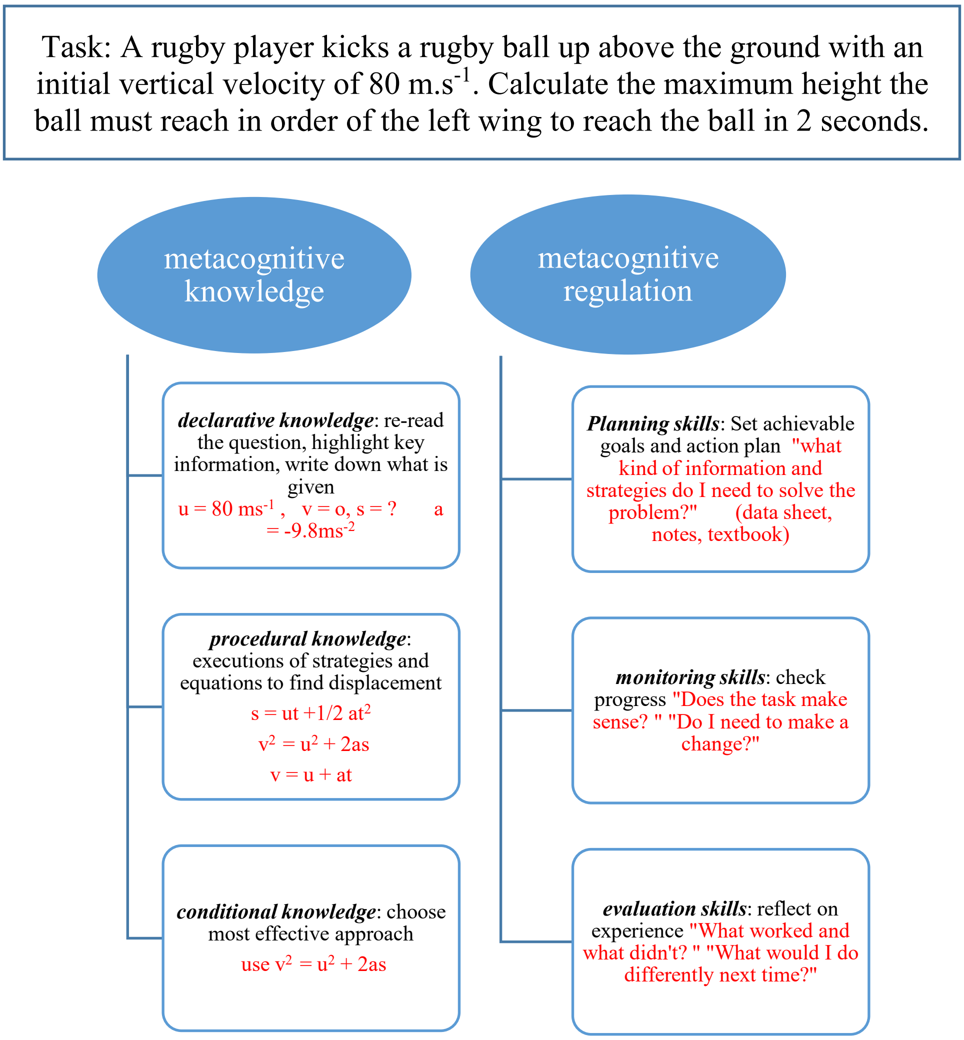

Figure 1. Components of Metacognition in Physics Problem Solving (Adapted from Schraw & Moshman, 1995).

The pupil may have to re-read the question, highlight key information, write down what is given and/or translate the question in the form of a diagram. Procedural skills are triggered when the pupil thinks of a list equation to find the height of the ball. Taking the upward direction to be positive and the downward direction to be negative and knowing that at maximum height the ball's velocity is zero, the pupils use their conditional knowledge to select the most effective equation to solve the problem.

Within this process, the learner plans steps to reach goals, monitor the process, and evaluate the experience. Schraw and Moshman (1995) regard these processes as metacognitive regulation. This is shown in Figure 1 where the pupil plans to achieve goals and monitor progress to become proficient in solving problems of this type. A step towards mastery in solving these problems is to evaluate the learning experience once the problem has been solved. The meta-evaluation process reflects on the pupils' experience by considering "What worked and what didn't? " "What would I do differently next time?", "Do I need to repeat the process to achieve mastery?".

During this process of metacognitive problem-solving, the teacher must appreciate that pupils will work at different paces and levels. For most pupils' problems of the type above may be at a challenging level. To promote creativity, the pupils may be encouraged to write their strategy to solve problems of that type, create their problems with solutions, and discuss and explain equations of motion in terms of lived experience and indigenous knowledge in the form of a case study. More advanced pupils could write solutions to their own open-ended questions, create an analogy to describe key concepts, and/or design an experiment to test the hypothesis using scientific enquiry. These creativity-stimulating activities could be given once pupils have achieved mastery of the given problems.

The identities include social roles, relationships, and memberships during interaction and group activities (Oyserman, 2015). This is where the socio-cultural role of the learner's lived experience comes into play. The primary objective of the teacher is to ensure that the learner becomes a proficient problem solver. The metacognitive process is not fluid, and pupils may struggle to solve the problem. When the learner struggles to solve the problem and cannot solve it without social interventions, the learner has reached the zone of proximal development (ZPD) (Vygotsky, 1981). This is where social-constructive learning takes place and where more able peers, or the teacher, guide the learner towards a solution to the problem. Social roles and relationships are constructed during this learning process. The component of identity of the IBM is the focus during this experience. The cognitive skills and meta-skills of physical sciences are passed down from more able pupils and teachers to less able pupils to guide them socially towards the point of success during problem-solving. This is known as the Vygotskian approach. Success is achieved when the learner can work independently (non-Vygotskian) to solve similar problems in different contexts. Social, cognitive, and metacognitive skills are fostered creatively by pupils working as a team which is facilitated by the teacher.

Theoretical Framework

The element of metacognition refers to the tendency of physical sciences pupils to intentionally evaluate and reflect on hypothesises concerning the conclusions and outcomes in terms of their lived experience. The metacognitive ability of the pupil is shaped via socio-cultural interactions within the learning environment which is aligned with the pupils' lived experience (van der Plas et al., 2021). This study constantly considered the four main theories which are set out below:

1. Oyserman's (2015) identity-based motivation (IBM) theory is a psycho-social theory that interplays culture, identity, and metacognition which evaluates and reflects on hypotheses with respect to the

conclusions and outcomes in terms of the lived experience of the physical sciences learner.

2. Zone of Proximal Development (ZPD) (Vygotsky, 1981). The ZPD theory provided insight into observing metacognitive awareness through a sociocultural setting.
3. The collateral learning theory in terms of cultural border crossing, where pupils move between their lived culture and the culture of modern science to make sense of the world (Aikenhead & Jegede, 1999).
4. Fourthly there are components of metacognition in physical sciences problem solving (Schraw & Moshman, 1995).

Methodology

The researcher used the mixed methods design in this study. The technique used was sequential timing where the researcher used data and analysis of data of one type, after the data analysis of another type (Baidee et al., 2012). Concurrent triangulation of the qualitative and quantitative data analysis was done by integrating and critically comparing the data sets to draw conclusive findings with strong validity. The research benefited from the combined strengths of qualitative and quantitative methodologies because the effectiveness of one approach was used to counteract the shortcomings of the other (Ary et al., 2019).

The researched sample population consisted of 151 Grade 11 physical sciences pupils from seven schools in the Verulam, Tongaat and Phoenix central districts in the South African province of KwaZulu-Natal. The schools were non-paying fee schools, and pupils were from schools who came from "below the upper-middle-income" socio-economic backgrounds which World Bank Group (2023) stated mirrored the majority of South African people. The researcher felt that the Grade 11 pupils were a good fit for the study because they had studied physical sciences for at least a year and a half, and they were not involved in the matric examination.

The first phase of the sequential timing data gathering was to analyse the Curriculum and Policy Statement (CAPS) of the physical sciences document. The CAPS document was scrutinised and analysed to extract meaning, gain understanding, and develop pragmatic knowledge in answering RQ1: "To what extent does the physical sciences curriculum promote the cultural worldview of the pupils?".

The second phase of the data gathering was the completion of the Science Attitude Questionnaire (SAQ) adapted from work done by Abd-El-Khalick et al. (2015) (see Appendix). The SAQ focussed on Pupils' attitudes towards studying science and their cultural attitudes. This informed the researcher in answering (RQ2): The SAQ has 54 questions which measure pupils' personal experiences as well as external factors relating to the pupils' attitude towards science. Below is a breakdown of opinion statements associated with their respective constructs of the SAQ:

- positive attitude towards science–nos. 1; 6; 9; 12; 15; 19; 21; 22; 25; 28; 32; 39; 45
- negative attitude towards science–nos. 2; 7; 8; 14; 16; 20; 33; 41; 42; 36; 44
- future intention for study in science–nos. 5; 11; 18; 23; 27; 40
- impact of science on our daily lives–nos. 4; 17; 26; 30; 34; 37
- science in school–nos. 3; 10; 13; 35

- approval by friends and family–nos. 24; 29; 31; 38; 43
- cultural influence on science attitude–nos. 46-54

Cronbach's alpha measured the reliability and the internal consistencies of the construct within the SAQ (Tavakol & Dennick, 2011). Alpha values less than 0.6, were indicative of a poor correlation between items and hence these items were discarded during analysis (Tavakol & Dennick, 2011). The approval of friends and family, and cultural influences constructs scored too low to be considered reliable (see Table 1).

Table 1. Reliability of the SAQ

Construct	Question numbers	Cronbach's Alpha
Positive attitude towards science	*1;6;9;12;15;19;21;22;25;28;32;39; 45*	0.85
Negative attitude towards science	*2;7;8;14;16;20;33;36;41;42;44*	0.73
Future intention of the study in science	*5;11;18;23;27;40*	0.82
Science in school	*3;10;13;35*	0.75
Impact of science on our daily lives	*4;17;26;30;34;37*	0.71
Approval by friends and family	*24;29;31;38;*	0.48
Cultural influence on science attitudes	*46-54*	0.42

Therefore, they were not dealt with as constructs in this part of the research but were considered in the qualitative part of the research. Interviews of Grade 11 physical sciences pupils and the teachers formed the basis of phase 3 of the research. Focus group interviews collected data from many participants simultaneously. This was the most effective strategy for interviewing 151 pupils within the given time frame. The researcher had group discussions with the pupils and used the interview schedule to guide the questioning. The groups ranged between four to six pupils. All pupils took part in the interviews in which the medium of communication was English. Each interview lasted between 10 and 12 minutes. The researcher guided the discussions, monitored, and noted the responses verbatim, and used member checks to validate the responses to the interview questions. Interview schedules assessed the pupils' opinion about the conflict between their family culture and the micro-culture of physical sciences by asking the following questions: "To what extent does the physical sciences curriculum respect your culture?"; "Would you be more inspired if there were more African values and culture in the physical sciences curriculum?"; "What changes do you think is needed in the physical sciences course to encourage more pupils to excel and be more motivated towards physical sciences in the future? This phase gave a deeper insight into the analysis of the four research questions.

During the final phase of the research, the researcher used the observation protocol as a research instrument to observe the cultural dimension of metacognition during the teaching and learning process. The focus was to evaluate the multiple worlds of the pupils in terms of their various microcultures, as well as sociocultural learning in terms of the ZPD. This part of the research consisted of the lesson observations of Grade 11 physical sciences classes. The observation protocol was filled tabulated and sequentially analysed.

Findings

Phase 1

The document analysis found that the CAPS stated one of its aims was to promote the inclusion of indigenous knowledge out of respect for the rich history and heritage of South Africa and also to promote the values in the South African constitution (DBE, 2011). It also stated that scientific and technological knowledge in the physical sciences curriculum acknowledges the knowledge systems of the indigenous people as a source of many innovations and developments, even though some concepts conflict with modern scientific principles. These statements promote the holistic multiple worldviews (DBE, 2011). However, despite the physical sciences curriculum stating that it aimed to promote Indigenous knowledge systems within the physical sciences curriculum, the only advice given on teaching Indigenous knowledge was found in the guidelines for teachers referring to "the first people to make fire did so using friction" (DBE, 2011). There was a lack of evidence from the document analysis to conclude that the CAPS document promoted Indigenous knowledge effectively and creatively.

Phase 2

Descriptive Statistics for the Positive Attitude and Negative Attitude Construct of the SAQ

The positive attitude and negative attitude construct analyses were merged because the results complemented each other (see Table 2 and Table 3).

Table 2. Descriptive Statistics for a Positive Attitude towards Science Construct of the SAQ

Positive attitude towards science construct of the SAQ							
Questions	N	Minimum	Maximum	Mean	Std. Deviation	% response of 1 and 2	% response of 3 and 4
1	147	1	4	3.25	.508	3.4	96.6
6	151	1	4	3.16	.612	10.6	89.4
9	146	1	4	2.98	.906	24.0	76.0
12	150	1	4	2.08	.700	75.3	24.7
15	150	1	4	2.88	.827	28.7	71.3
19	151	1	4	3.21	.686	11.3	88.7
21	151	1	4	3.39	.611	5.3	94.7
22	151	1	4	3.18	.633	8.6	91.4
25	150	1	4	3.11	.719	16.7	83.3
28	151	1	4	2.79	.899	31.8	68.2
32	150	1	4	3.12	.665	14.0	86.0
39	148	1	4	3.68	.498	31.1	68.9
45	150	1	4	3.11	.848	20.0	80.0
			Average	**3.07**		**21.6%**	**78.4%**

The positive attitude construct assessed the pupil's motivation and enthusiasm for science, whilst the negative attitude construct of the SAQ assessed pupils' demotivation and disinterest in science. Overall, the descriptive statistics showed that 84.8% of pupils selected options 1 (strongly disagree) and 2 (disagree) for the negative attitude construct which meant they did not align themselves with a negative attitude towards science while 78.4

% of them chose option 3 (agree) and 4 (strongly agree) for the positive attitude construct which meant most pupils had a positive attitude towards science. However, when asked question 12, "Science is easy for me?", 75.3% of the pupils selected option 1 or 2. This meant most of the pupils found science difficult.

Table 3. Descriptive Statistics for Negative Attitude towards Science Construct of the SAQ

Negative attitude towards science construct of the SAQ							
Question	N	Minimum	Maximum	Mean	Std. Deviation	% response of 1 and 2	% response of 3 and 4
2	148	1	4	1.43	.766	91.2	8.8
7	146	1	4	1.73	.773	88.4	11.6
8	149	1	4	2.07	.819	75.2	24.8
14	148	1	4	1.76	.762	85.4	14.6
16	150	1	4	1.77	.725	89.3	10.7
20	151	1	4	1.83	.844	82.1	17.9
33	147	1	4	1.75	.826	85.0	15.0
36	148	1	4	1.95	.852	78.4	21.6
41	150	1	4	1.25	.504	97.4	2.6
42	149	1	4	2.21	.910	67.8	32.2
44	149	1	4	1.50	.684	93.0	7.0
			Average	**1.75**		**84.8%**	**15.2%**

Descriptive Statistics for the Future Intention of Study in Science Construct of the SAQ

Future interest in science construct assessed pupils' future intention to further their studies in science (see Table 4 below), despite a 69% majority of the pupils' responses steering towards "agree" and "strongly agree" to considering a future in science, 78% of the pupils felt they would not become scientists in the future (question 18). This is concerning, because this implies that most of the pupils studying physical sciences do not see themselves becoming scientists.

Table 4. Descriptive Statistics for Future Intention in Science Construct of the SAQ

Future intention in science construct of the SAQ							
Questions	N	Minimum	Maximum	Mean	Std. Deviation	% response of 1 and 2	% response of 3 and 4
5	150	1	4	3.06	.936	23.3	76.7
11	150	1	4	3.41	.625	6.0	94.0
18	150	1	4	2.05	.758	78.0	22.0
23	150	1	4	2.91	.843	28.0	72.0
27	150	1	4	3.19	.781	16.0	84.0
40	148	1	4	2.83	.803	33.8	66.2
			Average	**2.91**		**30.9%**	**69.1%**

Descriptive Statistics for the Impact of Science Construct of the SAQ

The impact of science construct assessed pupils' awareness of science in their everyday lives. The 88% majority of pupils gave responses tending towards "agree" and "strongly concluding that a large majority of pupils were aware that science plays an important role in their everyday lives (see Table 5).

Table 5. Descriptive Statistics for the Impact of Science Construct of the SAQ

Impact of science on our daily lives construct of the SAQ							
Questions	N	Minimum	Maximum	Mean	Std. Deviation	% response of 1 and 2	% response of 3 and 4
4	148	1	4	3.20	.791	14.9	85.1
17	151	1	4	3.12	.711	17.2	82.8
26	150	1	4	3.46	.701	8	92.0
30	149	1	4	3.32	.658	9.4	90.6
34	148	1	4	3.07	.706	16.8	83.2
37	147	1	4	3.40	.616	5.4	94.6
			Average	**3.26**		**12.0%**	**88.0%**

Descriptive Statistics for the Science in School Construct of the SAQ

The science in-school construct assessed pupils' attitudes towards science in their learning environment. Overall, the descriptive statistics for the construct suggested that an average of 79.6% of pupils had positive attitudes towards science in their learning environment (see Table 6).

Table 6. Descriptive Statistics for the Science in School Construct of the SAQ

Science in school construct of the SAQ							
Questions	N	Minimum	Maximum	Mean	Std. Deviation	% response of 1 and 2	% response of 3 and 4
3	147	1	4	2.99	.731	21.8	78.2
10	150	1	4	3.09	.854	17.3	82.7
13	150	1	4	3.27	.858	13.3	86.7
35	148	1	4	2.84	.871	29.1	70.9
			Average	**3.05**		**20.4%**	**79.6%**

Phase 3

When asked "To what extent does the physical sciences curriculum respect your culture?" during the interviews, 84% of the pupils used words such as "the curriculum does not force views on us"; "nothing about disagreeing with my culture"; "textbook does not have anything that offends me"; "unbiased"; "respects culture as a whole"; "yes"; "does not say God does not exist"; "does not say religion is wrong"; "physics books have informed us about culture"; "does not affect culture". The pupils felt positive about the physical sciences curriculum respecting their culture. To the question, "Would you be more inspired if there were more African values and culture in the physical sciences curriculum?", 61 % of the pupils used words like "yes", "more interesting"; and "more aware of African culture"; "proud of African culture"; "makes physical sciences easier to understand" to suggest that more African culture is needed in the physical sciences curriculum. When asked the final question, "What changes do you think are needed in the physical sciences course to encourage more pupils to excel and be more motivated towards physical sciences in the future?", 60 % of the pupils mentioned that more practical work should be implemented together with better equipment, and a further 43% of the pupils suggested that better technology such as computers would be beneficial to their progress. Despite only 35% of pupils stating that physical sciences should be taught in isiZulu, this was regarded as part of the focus in the discussions and recommendations part of the study because it was considered significant.

Phase 4

The researcher used the observation protocol to assess metacognitive awareness whilst evaluating the cultural dimension whilst fostering metacognition. The focus of this discussion was only on the cultural dimension. In terms of the pupils' family culture and lived experience versus the micro-culture of science, there was no evidence to show support for the pupils' indigenous knowledge. For example, when the lesson on electricity was observed there were opportunities to link the Zulu myth of the lightning bird or impundulu, or the traditional belief of the Heteropyxis natalensis tree which is believed to have protective properties against lightning. However, one teacher did relate the electricity lesson to the streetlights which does link the lesson to the pupils' lived experience in real life context. Furthermore, the lessons were teacher-centred and very exam-orientated. There were missed opportunities to promote the Vygotskian socio-cultural theory and the idea of multiple worlds view in a holistic approach to the teaching and learning environment.

Discussion and Recommendations

Research Question 1

By referring to the document analysis of phase 1 in answering RQ1: "To what extent does the physical sciences curriculum promote the cultural world view of the pupils?", it was found that the CAPS aim promoted the inclusion of indigenous knowledge within the physical sciences curriculum in terms of the South African constitution. Within the CAPS document it further stated that scientific and technological knowledge in the physical sciences curriculum acknowledges the knowledge systems of the indigenous people as a source of many innovations and developments, even though some concepts conflict with modern scientific principles. At first glance one may draw the conclusion that the physical science curriculum fosters the holistic multiple world view to solve the cultural border crossing experience of the pupils. However, the physical sciences curriculum lacks direction in informing the teachers on how to implement cultural knowledge and experience during the teaching and learning process.

The lack of evidence to promote indigenous knowledge within the teaching and learning process may be due to the curriculum designers expecting the teachers to promote indigenous knowledge in an effective and creative way. Studying science in its ideal sense emphasises aims, logic, facts, and is depersonalised. South African pupils are motivated by the beauty, social interconnectedness, compassion, and spiritual nature of science in their society (Keane, 2015). Pupils are more motivated in science if their values and culture are included. This limits the collateral damage of "cultural border crossing". Motivation plays a crucial role in promoting and stimulating metacognition (Efklides et al., 2001; Hartman, 2001; Larkin, 2009; Myers, 2008). A holistic curriculum that motivates indigenous pupils must have indigenous values and culture embedded in the curriculum (Fien, 2010). This promote the idea of the pupils' multiple worlds which is experienced within and out with the physical sciences classroom in order to resolve the conflicts. The pupils then accept and rationalise their family culture and live experiences together with the micro-culture embedded in science.

The triangulation of data from the lesson observations in phase 4 concludes that indigenous knowledge is not promoted despite there being opportunities to integrate this cultural knowledge within the physical sciences curriculum. The lessons were teacher-centred, and exams-driven rather than focusing on critical thinking, creativity, and metacognition. In conclusion there are crucial gaps in the physical sciences curriculum to promote the cultural world view of the pupils to foster holistic understanding to revolve the conflicts of multiple worlds. Curriculum designers need to be more explicit as to how indigenous knowledge be integrated with each topic statements of the curriculum.

Research Question 2

The descriptive analysis of the SAQ in phase 2 of the research formed the basis of the evaluation in answering RQ2: “What were the pupils’ attitudes towards science?”. The descriptive statistics for the positive attitude construct of the SAQ indicate that an average response of 79.4% points to the pupils feeling motivated and optimistic about science. The 88% majority of pupils were aware that science plays a considerable role in their everyday lives. Motivation plays a significant role in science. It is very apparent from the data that the pupils are very motivated in studying science.

However, 75.3% of pupils feel that science is difficult. This should not be taken as a negative. It should be accepted that science is a cognitively challenging subject. Furthermore, the analysis of future intention in science found that 78% of the pupils felt they would not become scientists in the future. This could be because a majority of 75.3% of pupils felt that science is difficult. Triangulating the data from the lesson observation in phase 4 suggested that social construction of knowledge in the pupils ZPD was restricted due the less effective teacher-centred approach dominating. This may indirectly further burden the pupils in thinking science is more difficult that it is. A multidimensional socio-cultural metacognitive model which promotes the Vygotskian approach to learning within the ZPD is a more effective teaching and learning approach which will reduce the stress and demotivation of the pupils in thinking science is difficult.

Furthermore, the acceptance of the challenging nature of science and persevering through the experience within a multidimensional socio-cultural metacognitive model builds academic tenacity. Dweck (2006) promotes the perception of a growth mindset, where pupils are persuaded to take risks, trust in themselves, and modify their efforts if they do not initially succeed. Dweck’s studies revealed that pupils with a fixed mindset exhibited a deterioration in attainment, whilst pupils with a growth mindset showed an extensive growth in attainment (Dweck, 2006). A further dimension to the metacognitive model must include academic tenacity in terms of a growth mindset. To sum up, the pupils have a very positive outlook towards their experience in studying science, however the due to less effective teacher-centred approach and pupils’ poor academic tenacity they find science more challenging than it actually is. For these reasons they do not see themselves as future scientists. This is very concerning at a national level because countries like South Africa trust that scientific knowledge and advanced technologies can provide solutions to most of the problems the country faces (Dahlman, 2008; Lockheed & Levin, 1993; Riley, 2001).

Research Question 3

RQ3: “What are the views held by the sample population on “cultural border-crossing?”, deconstructed the impact of the multiple world views of the pupils in terms of lived experience and the indigenous knowledge with the microculture of modern science. Using the data analysis of the pupil interviews and focusing on their cultural experience most pupils do not seem to have cultural conflicts while studying physical sciences. Eighty four percent of pupils stated the physical sciences curriculum does not disrespect their cultural beliefs. In spite of pupils not having conflicts with the multiple worlds view whilst studying science, 61% of pupils stated the physical sciences course would be more exciting if indigenous culture was included in the course. This analysis aligns with motivation factor linked to the holistic approach to a culturally integrated physical sciences course.

Furthermore, 35% of pupils stated they would prefer to be taught physical sciences in isiZulu which is an important point. This implies that indigenous pupils are at a disadvantage when studying science in a language which is not their mother tongue. This may be compounded by the perception that science is difficult which was discussed SAQ during phase 2 of the analysis. The researcher advocates that physical sciences should be taught in the indigenous pupils’ mother tongue.

The pupils are exposed to science and technology in their lived experience. Their exposure to science and technology within their lived experience may be considered to be an additional microculture. There has been no direct mention by the pupils of this lived experience, but 60% of pupils felt their physical sciences lessons lacked practical activities and equipment to support practical work, while 43% of pupils also mentioned that to improve the course, information technology is required in the classroom. This implies that the microculture of the pupils in terms of science and technology within their lived experience is not translating into their classroom experience. This was seen during the classroom observations in phase 4 of the research when only one teacher was observed relating the lesson to the pupils’ real-life context. This further shows that the multiple worlds conflict is not resolved in a holistic way. To resolve this, the lessons should have a real-life context that the pupils could relate to and have hands-on practical implications in which the pupils could be actively and socially involved.

The issue of information technology is very relevant and important in the context of science and technology, however, due to limited funding of the schools it would be very difficult to solve. To answer RQ 3, despite the pupils feeling that the physical sciences curriculum does not disrespect their culture, there are conflicts in terms of IBM in a psycho-social cultural setting in terms of indigenous culture, lived culture, identity, and the microculture of science.

Seven-phase socio-cultural metacognitive model to promote a growth mindset and creativity in physical sciences Real world context and indigenous knowledge must be integrated within the teaching and learning process to promote the holistic approach to a culturally integrated multiple worlds view to the physical sciences course to resolve conflict among the indigenous culture, lived experience, and the microculture of modern science. Furthermore, the model must foster a growth mindset in order to build academic tenacity to ensure pupils persevere trough science despite finding it difficult. This may encourage them pursue future studies in science.

To make this model inclusive, physical sciences must be offered in the indigenous pupils' mother tongue. Parallel studies to this research by Rajcoomar et al. (2022) used work by Hollingworth and McLoughlin (2001), Nottingham (2017), and Vygotsky (1981) to create a merged eight-phase, ZPD, and the learning pit metacognitive model for physical sciences. It was a multidimensional model which included the three-pronged approach encompassing the Vygotskian principles of ZPD to promote sociocultural learning, formal explicit metacognitive theory to foster metacognitive awareness explicitly, and the non-Vygotskian approach to independent problem solving. The model promoted a growth mindset through the learning pit. Despite being an explicit multidimensional metacognitive model, it did not integrate culture within the model.

Figure 2 adapted the model by Rajcoomar et al. (2022), to promote creativity and critical thinking. It is called the seven-phase socio-cultural metacognitive model to promote a growth mindset and creativity in physical sciences.

Figure 2. A Seven-phase Socio-cultural Metacognitive Model to Promote a Growth Mindset and Creativity in Physical Sciences

It is important to note that the component of culture was only one part of the multidimensional metacognitive model. Each part of the model interacts with other components and cannot be discussed in isolation. Below is the discussion of the key components of the holistic socio-cultural metacognitive model which promotes creativity in physical sciences.

By referring back to the problem discussed in the IBM part of the literature review the model is explained as follows. During phase 1 the micro-culture of the pupils' family, in terms of indigenous knowledge and the lived experience of the real-life context, must be discussed to resolve the conflicts of the multiple world views of the pupils and to motivate the pupils. Using the modified CAPS physical sciences document which explicitly promotes cultural knowledge of the pupils, the teacher will find an indigenous knowledge example linked to the topic. For example, indigenous communities such as the San Bushmen (Koisan) have acquired hunting tools and skills. They had the practical know how of projectile motion, albeit the empirical understanding of equations of motion to consider factors such as the angle, speed, distance, and time of their projectiles to effectively hit their targets. The lived experience of the pupils could be linked to a sports like rugby, netball, or football to connect the topic to the real-world context in which the pupils can relate to. The teacher may utilise the teacher expert model to prepare the pupils to solving problems on the section of equations of motion.

During phase 2 a challenging problem is presented. If the pupil moves from directly from phase 2 to phase 6, real learning has not taken place. By skipping the steps, the pupil does not experience cognitive struggle, opportunities to achieve a growth mind set, and metacognitive skills practice. Those experiences are key to achieving a well-rounded metacognitive and creative pupil. The model may work differently for pupils with varying educational needs. It should be differentiated to suit the learning needs of the pupils. If the phases are skipped by the pupils, the activity should be differentiated by the teacher asking the pupils to generate their own questions with possible solutions, connect the problem to real life situations in terms of a case study, create an analogy to describe key concepts, and/or design an experiment to test hypothesis using scientific enquiry as discussed in the IBM part of the literature review. The experiment activity could increase the practical work done by the pupils as discussed in the teacher interview analysis part of the study. This should be done as an individual activity or as part of a collaborative activity to assess and evaluate the skill of creativity of the pupils. The teacher should provide formative feedback to guide the pupils to success and allow the pupils to work at their own pace. This encourages a learner-centred approach as compared to a teacher-centred approach, and holistic approach compared to an exam driven approach.

It is expected that most pupils will not go directly to phase 6. During phase 2 the pupils are guided in using their declarative knowledge to interpret information whilst planning strategies to solve the problem as discussed in IBM part of the literature review. Phase 3 is where the pupil cannot solve the problem. This is described as the pupil falling into the learning pit. The pupil feels emotions of struggle and confusion. Their first reaction is to give up. They feel science is difficult as discussed SAQ of the data analysis part of the study. This should be motivated as a normal part of the science learning process. It is appropriate to feel confused and struggle. The learner may not solve the problem at this point, but must be encouraged to persevere. A growth mindset must be encouraged to get out of the learning pit. The teacher should prompt ways in which the pupil could escape the learning pit.

During phase 4 the pupils are encouraged to use non-Vygotskian attempts to solve the problem without social interaction. The pupil must exhaust its cognitive resources by thinking of all avenues to solve the problem. The pupil may resort to notes and textbooks. Some pupils may be successful at this point and thus escape the learning pit. They may be required to repeat phases 2 to 4 until mastery. At this point the pupils must be given differentiated activities similar to the ones given to the pupils who went directly from phase 2 to phase 6 in order to promote creativity. It must be noted that this differentiated activity must start at phase 2 and sequentially move to phase 6. These processes must be repeated for mastery. The activities are individualised to the learning needs of every pupil.

Some of the pupils exhaust the cognitive and physical resources and not solve the problem without social intervention. This is phase 5 of the process and is called the ZPD. The pupil requires assistance from more able peers or the teacher in order to succeed. Procedural and conditional skills are socially constructed and practiced during this part of the learning process. The teacher encourages metacognitive monitoring of progress as well as giving constructive feedback during the process. Procedural, conditional, and metacognitive monitoring were discussed in the IBM part of the literature review. This collaborative process promotes creative thinking and teamwork.

Once the pupils reach phase 6, they must be encouraged to repeat the process by solving different problems of the same type. Once mastery is reached, they may be given more cognitively challenging tasks as discussed above to foster creativity and metacognition. The sequential repetition of phases 2 to 6 provides practice to enhance the skills of creativity and metacognition. Once the process has been concluded, which in most cases will be due to time constraints the pupils may move to phase 7 of the model. This the metacognitive evaluation phase which was discussed in the IBM part of the literature review. The pupils reflect on their learning experience. They evaluate on what worked and what did not work and how they may improve their learning. Creativity is encouraged by the pupils being encouraged to create their own learning model and strategies that may work for them. During each step of the process the teacher must assess the efforts of the pupils using formative feedback.

This model may be adapted to suit the needs of the pupils and teachers and should be displayed in the front of the class as a teaching tool. During each stage of the teaching and learning process the teacher must make reference to the model to show the pupils where their learning is with reference to the various phases. Using this model for as a guide for all the lessons allows repetition of creative thinking skills and metacognitive skills which will lead to mastery of the skills. Phase 1 and phase 5 of the model promoted the teacher expert approach in learner-centred environment as opposed to a less effective teacher-centred approach. This gives the pupils a first-hand experience in utilising key skills without needing to understand the complexities of metacognitive and creative thinking theory. The model allows differentiation in a learner-centred environment where pupils take ownership of their learning and work according to their individualised needs. Socialcultural learning is encouraged with the aim of the pupil working independently. Assessing creative thinking and metacognition in reports, discussions during parent evenings, and feedback talks with the pupils will further foster creativity and metacognition in an effective way. This model favours skills-based learning as opposed to content driven, rote learning approach.

The factor of time must be taken into consideration whilst implementing this model. When trying to get through an extensive content driven curriculum teachers may be forced to focus on completing the curriculum instead of fostering metacognition and creativity. Curriculum designers need to restructure the curriculum to accommodate mastery of metacognitive skills and creative thinking instead, of a broad content driven curriculum which steers towards surface level of understanding and rote learning.

Conclusion

The majority of the pupils find physical sciences difficult, and they will not pursue a further study in science in the future. Most pupils suggested that integrating indigenous knowledge within the physical sciences curriculum would motivate them, whilst a significant minority of the pupils favoured studying physical sciences in isiZulu. However, the physical sciences curriculum and the lessons observed did not support the microculture of the pupils' indigenous knowledge and their lived experience to resolve the conflict with the microculture of science. The pupils' teaching and learning experience were teacher-centred and exam-driven. These experiences stifle creativity and metacognition which leads to demotivation in terms of thinking science is harder than it is and not wanting to pursue a career in science.

The holistic socio-cultural metacognitive model to promote creativity in physical sciences constructed in this research includes sociocultural construction of knowledge through the ZPD, integrates indigenous knowledge and real-life context in physical sciences, promotes a growth mindset, and fosters metacognition and creativity repeatedly. The seven-phase socio-cultural metacognitive model to promote a growth mindset and creativity in physical sciences will resolve the multiple worlds conflict of the pupils in a holistic way, focuses on the pupils individualised needs in a learner-centred way, steers away from focusing on exams by emphasising on metacognitive and creative thinking skills, and promotes academic tenacity.

References

Aikenhead, G.S., & Jegede, O.J. (1999). Cross-cultural science education: a cognitive explanation of a cultural phenomenon. *Journal of research in science teaching*, 36 (3), 69-287. https://doi.org/10.1002/(SICI)1098-2736(199903)36:3<269::AID-TEA3>3.0.CO;2-T.

Ary, D., Jacobs, L.C. Sorensen, C., & Walker, D. A. (2019). *Introduction to research in education* (10^{th} ed.). Cengage Learning.

Badiee, M., Wang, S. C., & Creswell, J. W. (2012). Designing community-based mixed methods research. In D. K. Nagata, L. Kohn-Wood, & L. A. Suzuki (Eds.), *Qualitative strategies for ethnocultural research* (pp. 41–59). American Psychological Association. https://doi.org/10.1037/13742-003

Dahlman, C. (2008). Technology, globalisation, and international competitiveness: challenges for developing countries. In D. C. O'Connor & M. Kjollerstrom (Eds.), *Industrial Development for the 21st Century*, 29-83. United Nations

DBE (Department of Basic Education). (2011) *Curriculum and Assessment Policy Statement, Physical Science. Pretoria*. Available https://www.education.gov.za/Portals/0/CD/National%20Curriculum%20Statements%20and%20Vocational/CAPS%20FET%20%20PHYSICAL%20SCIENCE%20WEB.pdf?ver=2015-01-27-154258-683

Dweck, C. S. (2006). *Mindset: Changing the way you think to fulfill your potential*. Random House Publishing Group.

Efklides, A., Kuhl, J., & Sorrentino, R. M. (2001). *Trends and prospects in motivation research*. Kluwer Academic Publishers. https://doi.org/10.1007/0-306-47676-2

Fien, J. (2010). Indigenous knowledge & sustainability. *Teaching and Learning for a Sustainable Future*. Retrieved May 10, 2023, from http://www.unesco.org/education/tlsf/mods/theme_c/mod11.html

Hacker, D. & Bol, L. (2004) Metacognitive theory: Considering the social cognitive influences. In D.M. McInerney, & S.V. Elten (Eds.), *Big theories revisited*, 275-298. Information Age Publishing, Connecticut.

Hartman, J. H. (Ed.). (2001). *Metacognition in learning and instruction: theory, research, and practice* (19). Springer Science & Business Media.https://doi.org/10.1007/978-94-017-2243-8

Hartman, H.J. & Glasgow, N.A. (2002). *Tips for the science teacher: research-based strategies to help students learn.* Sage Publishing Company, California.

Hollingworth, R.W., & McLoughlin, C. (2001). Developing science students' metacognitive problem-solving skills online. *Australian Journal of Educational Technology*, 17(1), 50–63.

https://doi.org/10.14742/ajet.1772

Human Sciences Research Council. (2019). TIMSS South Africa 2019 Grade 9 Fast Facts. https://www.timss-sa.org/key-finding/timss-south-africa-2019-grade-9-fast-facts (Accessed: 27 July 2023).

James, C. A. (2004). Review of Science and Other Cultures: Issues in Philosophies of Science and Technology In R. Figueroa & S. Hardin (Eds), Essays in Philosophy, 5(1), 182–189. https://doi.org/10.5840/eip20045156

Jost, J. T., Kruglanski, A. W., & Nelson, T. O. (1998). Social Metacognition: An Expansionist Review. *Personality and Social Psychology Review*, 2(2), 137–154.

Keane, M. (2015). Why indigenous knowledge has a place in the school science curriculum. *Journal of Research in Science Teaching*, 52(10), 1405-1412.

Larkin, S. (2009). *Metacognition in young children.* Routledge Publishing. https://doi.org/10.4324/9780203873373

Levin, H., & Lockheed, M. (1993). *Effective Schools in Developing Countries* (1st ed.). Routledge. https://doi.org/10.4324/9780203816455

Mullis, I.V.S., von Davier, M., Foy, P., Fishbein, B., Reynolds, K.A., & Wry, E. (2023). PIRLS 2021 International Results in Reading. B*oston College, TIMSS & PIRLS International Study Center.* https://doi.org/10.6017/lse.tpisc.tr2103.kb5342

Myers, A. (2008). *Factors that predict the use of metacognitive strategies in the middle school classroom*. ProQuest Information and Learning Company.

Nottingham, J. (2017). *The Learning Challenge Culture.* Corwin https://doi.org/10.4135/9781071873007

Helms-Lorenz, M., & Jacobse, A. E. (2008). Metacognitive skills of the gifted from a cross-cultural perspective. In M. F. Shaughnessy, M. V. J. Veenman, & C. Kleyn-Kennedy (Eds.), *Meta-cognition: A recent review of research, theory, and perspective,* 3 - 43. Nova Science Publishers. https://www.researchgate.net/publication/265384152_Metacognitive_skills_of_the_gifted_from_a_cross-cultural_perspective

Oyserman, D. (2015). *Identity-Based Motivation: Pathways to Success Through Identity-Based Motivation*. Oxford University Press. https://doi.org/10.1093/oso/9780195341461.003.0004

Oyserman, D., Fryberg, S. A., & Yoder, N. (2007). Identity-based motivation and health. *Journal of Personality and Social Psychology*, 93(6), 1011–1027. https://doi.org/10.1037/0022-3514.93.6.1011

Rajcoomar, R., Morabe, O. N., & Breed, B. (2022). Effectiveness in Fostering Metacognition: Analysis into the State of Metacognition within South African Physical Science Classrooms with the Aim of Improving Attainment. *Journal of Education, 204*(2), 337-350. https://doi.org/10.1177/00220574221104974

Riley, J. P. (2001). International development and science education: Issues and considerations. *Journal of International Cooperation in Education*, 4(1), 53-63.

Schraw, G., & Moshman, D. (1995). Metacognitive theories. *Educational Psychology Review, 7*(4), 351–371. https://doi.org/10.1007/BF02212307

SPSS Inc. 2016, IBM SPSS Statistics Version 23, Release 23.0.0., Copyright© IBM Corporation and its licensors, Available :< http://www-01.ibm.com/software/analytics/spss/>.

Abd-El-Khalick, F., Summers, R. Said, Z., Wang, S. & Culbertson, M. (2015) Development and large-scale validation of an instrument to assess arabic speaking students' attitudes toward science. *International*

Journal of Science Education. https://doi.org/10.1080/09500693.2015.1098789

Sutherland, D. (2005). Resiliency and collateral learning in science in some students of Cree ancestry. *Science Education*, 89 (4), 595-613.https://doi.org/10.1002/sce.20066

Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. *International Journal of Medical Education*, 2(1), 53–55. https://doi.org/10.5116/ijme.4dfb.8dfd

Thomas, G.P. (2002). Social mediation of metacognition. In D.M. McInerney, & S. Van Etten, (Eds.), *Research on sociocultural influences on motivation and learning*, 237-249. Information Age Publishing, Connecticut.

van der Plas, E., Zhang, S., Dong, K., Bang, D., Li, J., Wright, N., & Fleming, S. M. (2021). Identifying cultural differences in metacognition. https://doi.org/10.31234/osf.io/sjh7d

Vygotsky, L. S. (1981). *Mind in society*. Harvard University Press. https://doi.org/10.1017/s0033291700041507

World Bank Group. (2023). T*he World Bank in South Africa. The World Bank's strategy in South Africa reflects the country's development priorities and its unique leadership position at sub-regional and continental levels.* https://www.worldbank.org/en/country/southafrica/overview (Accessed 12 July 2023).

Yan, V. X., Oyserman, D. (2018). The world as we see it: the culture-identity-metacognition interface. In J. Proust & M. Fortier (Eds), *Metacognitive diversity: an interdisciplinary approach*. Oxford. https://doi.org/10.1093/oso/9780198789710.001.0001

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Appendix A. Ethics Approval Certificate

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ETHICS APPROVAL CERTIFICATE OF STUDY

Based on approval by the **Ethics Committee of the Faculty of Education Sciences (ESREC) on 20/01/2017** after being reviewed at the meeting held on **29/10/2015**, the North-West University Institutional Research Ethics Regulatory Committee (NWU-IRERC) hereby **approves** your study as indicated below. This implies that the NWU-IRERC grants its permission that, provided the special conditions specified below are met and pending any other authorisation that may be necessary, the study may be initiated, using the ethics number below.

Study title: Metacognition within physical science classrooms in two KwaZulu-Natal districts.

Study Leader/Supervisor: **Prof B Breed**
Project team: **R Rajcoomar & Dr N Morabe**

Ethics number: N W U - 0 0 4 4 8 - 1 5 - A 2

Application Type: N/A
Commencement date: 2015-10-29 **Expiry date**: 2017-12-31 **Risk:** N/A

Special conditions of the approval (if applicable):

- Translation of the informed consent document to the languages applicable to the study participants should be submitted to the ESREC (if applicable).
- Any research at governmental or private institutions, permission must still be obtained from relevant authorities and provided to the ESREC. Ethics approval is required BEFORE approval can be obtained from these authorities.

General conditions:

While this ethics approval is subject to all declarations, undertakings and agreements incorporated and signed in the application form, please note the following:

- *The study leader (principle investigator) must report in the prescribed format to the NWU-IRERC via ESREC:*
  - *annually (or as otherwise requested) on the progress of the study, and upon completion of the project*
  - *without any delay in case of any adverse event (or any matter that interrupts sound ethical principles) during the course of the project.*
  - *Annually a number of projects may be randomly selected for an external audit.*
- *The approval applies strictly to the proposal as stipulated in the application form. Would any changes to the proposal be deemed necessary during the course of the study, the study leader must apply for approval of these changes at the ESREC. Would there be deviated from the study proposal without the necessary approval of such changes, the ethics approval is immediately and automatically forfeited.*
- *The date of approval indicates the first date that the project may be started. Would the project have to continue after the expiry date, a new application must be made to the NWU-IRERC via ESREC and new approval received before or on the expiry date.*
- *In the interest of ethical responsibility the NWU-IRERC and ESREC retains the right to:*
  - *request access to any information or data at any time during the course or after completion of the study;*
  - *to ask further questions, seek additional information, require further modification or monitor the conduct of your research or the informed consent process.*
  - *withdraw or postpone approval if:*
    - *any unethical principles or practices of the project are revealed or suspected,*
    - *it becomes apparent that any relevant information was withheld from the ESREC or that information has been false or misrepresented,*
    - *the required annual report and reporting of adverse events was not done timely and accurately,*
    - *new institutional rules, national legislation or international conventions deem it necessary.*
- *ESREC can be contacted for further information or any report templates via Erna.Conradie@nwu.ac.za or 018 299 4656*

The IRERC would like to remain at your service as scientist and researcher, and wishes you well with your project. Please do not hesitate to contact the IRERC or ESREC for any further enquiries or requests for assistance.

Yours sincerely

Prof LA Du Plessis

Digitally signed by Prof LA Du Plessis
Date: 2017.01.27 08:46:49 +02'00'

Prof Linda du Plessis
Chair NWU Institutional Research Ethics Regulatory Committee (IRERC)

Appendix B. Science Attitude Questionnaire (SAQ) adapted from Abd-El-Khalick et al. (2015)

Science Attitude Questionnaire

Instructions

There are no "right" or "wrong" answers to the following questions. We are simply interested in your feelings about a number of issues related to science and science learning.

- Indicate the extent to which you agree or disagree with each the following statements.
- Place a check tick
- Tick **only one answer** for each question.
- – **If you "Strongly disagree" with a statement, then you should tick:**

Strongly disagree	Disagree	Agree	Strongly agree
✓	○	○	○

	Strongly disagree	Disagree	Agree	Strongly agree
1. I enjoy science	○	○	○	○
2. Learning science is **not** important for my future success	○	○	○	○
3. We do a lot of interesting activities in science class	○	○	○	○
4. Most people should understand science because it affects their lives	○	○	○	○
5. I will study science if I get into a university	○	○	○	○
6. I am sure I can do well on science tests	○	○	○	○
7. Scientific discoveries do more harm than good	○	○	○	○
8. I usually give up when I do **not** understand a science concept	○	○	○	○
9. Science is one of the most interesting school subjects	○	○	○	○
10. Teachers encourage me to understand concepts in science classes	○	○	○	○
11. Science classes will help prepare me for university	○	○	○	○
12. Science is easy for me	○	○	○	○
13. My science teachers are very good	○	○	○	○
14. I will **not** pursue a science-related career in the future	○	○	○	○
15. I like to watch TV programs about science	○	○	○	○
16. I **cannot** understand science even if I try hard	○	○	○	○
17. Science is useful in solving everyday life problems	○	○	○	○
18. I will become a scientist in the future	○	○	○	○
19. I look forward to science activities in class	○	○	○	○
20. A job as a scientist would be boring	○	○	○	○
21I like to learn more about science	○	○	○	○
22. I really enjoy science lessons	○	○	○	○
23. I will continue studying science after I leave school	○	○	○	○
24. My family encourages my interest in science	○	○	○	○
25. I am confident that I can understand science	○	○	○	○
26. We live in a better world because of science	○	○	○	○
27. I would enjoy working in a science-related career	○	○	○	○
28. I will miss studying science when I leave school	○	○	○	○

Science Attitude Questionnaire

	Strongly disagree	Disagree	Agree	Strongly agree
29. My friends like science				
30. Knowing science can help me make better choices about my health				
31. My family encourages me to have a science-related career.				
32. I really like science				
33. If I could choose, I would **not** take any more science in school				
34. Knowledge of science helps me protect the environment				
35. It helps me to learn science in the same language I use at home				
36. Scientific work is only useful to scientists				
37. Science will help me understand the world around me				
38. My friends do well in science				
39. If I work hard enough, I can learn difficult science concepts				
40. I will take additional science courses in the future				
41. Science lessons are a waste of time				
42. Scientists do **not** have enough time for fun				
43. People with science-related careers have a normal family life				
44. I do **not** like science				
45. My science teachers motivate me to learn science				
46. The science we learn respects my culture				
47. In science we learn about scientists from different cultures				
48. School science encourages people from my community to become scientists				
49. My country's history discourages me choosing science as a course to study				
50. There is a lot of black South African scientists that I look up to				
51. Science that I learn in school will help prepare me for university				
52. Science feels difficult when we learn things that is different from our culture				
53. My beliefs are different from the views we learn in science				
54. Science can be difficult because it uses words that I know but it has a different meaning				

Adapted from Summers, R.G. 2012. Development and validation of an instrument to assess precollege Arabic speaking students' attitudes toward science.

THANK YOU FOR COMPLETING THIS SURVEY