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Exploring Indigenous Knowledge Systems Integrated in Natural Sciences Practical Work in Selected South African Schools

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Abstract. This study used the nature of indigenous knowledge (NOIK) framework to explore indigenous knowledge systems (IKS) practices that were integrated when practical work in natural sciences was facilitated. In this interpretive explorative case study, data were collected by semistructured interviews, lesson observations and a focus group interview conducted with three purposively selected natural sciences teachers and two natural sciences district officials in the province of KwaZulu-Natal in South Africa. Thematic analysis techniques were used to analyze the data that were collected. Three findings on ways to integrate IKS in science practical work are the following. First, IKS was integrated in practical work through teaching of applied science and including the learners' lived experiences of local technologies to solve problems. Second, practical work that integrated IKS was conducted as empirical observations of natural phenomena, which included genetic variation of plants and animals, including human beings, animal behavior, using moon cycles and the movement of the sun to guide day-to-day, cultural and agricultural activities. Third, some of the IKS included myths and superstitions that distorted the public understanding of science but were nevertheless used to persuade people to uphold certain cultural practices. The study recommends comparing NOIK and the nature of science when integrating IKS in the classroom to enable learners to distinguish myths from scientific facts.

Keywords: indigenous knowledge systems; school science; practical work

1. Introduction

In South Africa, the subject of natural sciences is taught to learners in Grades 7–9. It is an integrated science subject that has four strands of knowledge: life and living, matter and materials, energy and change, and planet earth and beyond (Department of Basic Education, 2011). There have been frequent calls for

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indigenous knowledge systems (IKS) to be integrated into the teaching of natural sciences in South Africa (Ugwu & Diovu, 2016). These calls led to the recommendations contained in Curriculum and Assessment Policy Statement (CAPS) for natural sciences Grades 7–9, which was first implemented in 2012. In South Africa, the subject of natural sciences as taught in Grades 7–9 represents an integration of biology, chemistry, physics and earth and space sciences. The CAPS emphasizes conceptual development that is linked to the learner's context (Mudaly & Ismail, 2013) and the integration of IKS is one strategy to teach science with relevance. This study contributes to literature by exploring practical work as an instructional strategy to include IKS in the science curricula. This contribution adds to other literature findings that focused on the IKS concepts included in science curricula (Zinyeka et al. 2016; Tanyanyiwa, 2019; Chitera & Moyo, 2021). Other studies focused on teachers' perspectives on the teaching and inclusion of IKS in the classrooms (Naidoo & Vithal, 2014; Ogunniyi & Iwuanyanwu, 2024).

As recommended by the CAPS, practical work is central to the teaching of science and, in this study, we made the assumption that combining practical and theoretical work would ensure the implementation of IKS in the classroom. Practical work affords learners opportunities to engage in science process skills, such observation, data collection and analysis and drawing inferences, as well as handling and manipulating materials that include computer-based objects (Akuma & Callaghan, 2019a). Mudaly (2018) asserts that the integrating IKS in science practical work reduces the use of recipe-type instructional strategies. El Yazidi and Rijal (2024) agree that IKS enriches the teaching of science by providing practical solutions for problem-solving and sustainable development by bridging the gap between traditional wisdom and scientific inquiry.

IKS is defined as the knowledge and skills of indigenous peoples that they have known about and used for many generations; they include practices that evolved through trial and error and have proven capable of adapting to changes in the environment (Siambombe et al., 2018). IKS also include beliefs and epistemic views held by groups of people and which give them identity (Moore & Nesterova, 2020). According to Wilujeng and Prasetyo (2018), IKS are comprehensive knowledge systems that incorporate technologies and practices used by indigenous people for continued survival and adaptation in their immediate environments. Photo and McKnight (2024) describe IKS as transdisciplinary and applicable to learners' everyday lives. Among the IKS practices that drive communities are agricultural, food preservation and water collection and storage techniques, and animal husbandry and ethnic veterinary and ailment treatment practices (Abah et al., 2015; Zinyeka et al., 2016). These IKS concepts form a cultural matrix that embraces science and technology (Mpofu & Vhurumku, 2017). IKS practices can be used as case studies in lessons through through practical work activities.

According to De Coito and Gitari (2014), there exists a congruency between IKS and the tenets of the 21st century science education. The CAPS for natural sciences recommends that teachers employ a culturally relevant pedagogy that engages learners in ways that uphold their cultural identity while, at the same time, ensuring that they succeed academically (Mavuru & Ramnarain, 2017). IKS integration creates relevance for the content of natural sciences Grades 7–9 curricula, and practical work becomes one of the pedagogies for enabling implementation. Although Grades 7–9 natural sciences curricula prescribe that IKS must be integrated into lessons, the actual content and the instructional methods to be used are not specified (Seehawer, 2018). To close that gap, this study explored how the integration of IKS in natural sciences practical work was undertaken in selected classrooms. This approach contrasts with methods used to explore IKS practices by other studies, such as that of Mhlongo (2020), who collected IKS perspectives expressed through traditional oral stories in the form of customs, culture, folklore, and history. Accordingly, the main research question guiding the study is, *How can IKS practices be integrated in natural sciences practical work in some South African schools*?

2. The NOIK Systems and Practical Work

This study used the nature of indigenous knowledge (NOIK) and the nature of science (NOS) as a conceptual framework to understand the integration of IKS in natural sciences practical work. Scientific knowledge can be viewed as a product of scientific inquiry, and Akuma and Callaghan (2019b) recognize the role of inquiry-based practical work in the building of scientific theories and models. Practical work gives learners the opportunity to demonstrate skills, such as problem-solving, critical and analytical thinking and the application of knowledge in real-life settings (Oliveira & Bonito, 2023).

In comparing the NOS and the NOIK, Barnhardt and Oscar Kawagley (2005) acknowledge that both can be developed through empirical observations of natural settings. While the NOIK is context and culture based, the NOS is discipline based and gives rise to many branches of science. As a result, the NOS becomes part of the whole (Barnhardt & Oscar Kawagley, 2005), while the NOIK is holistic because of its transdisciplinary nature (Lipe, 2023). The NOIK may incorporate myths and superstitions, in contrast to the NOS, which is more objective. Nyhan (2020) and Bantubilli et al. (2022) assert that myths may distort the public perception of science. Like IKS, myths and superstitions are driven by group identity, and they are used to validate practices and beliefs. Myths and superstitions often create illusions of cause and effect, resulting in erroneous beliefs being created regarding scientific phenomena (Griffiths et al., 2019).

While the NOS is about understanding how things occur, the NOIK is about both understanding natural phenomena and applying that knowledge to the daily activities of people. Consequently, bringing the IKS of the learners' backgrounds into science classrooms helps to bridge the gap between life and learning experiences (Bossér, 2024). Both knowledge systems can remain stable over time and can therefore be used as guiding principles and epistemologies (Barnhardt & Oscar Kawagley, 2005). Accordingly, communities use IKS to make meaning of the world around them, including natural phenomena, and guide the interaction of people with their environment. Some IKS concepts can be used to explain meteorological and climatic events (Zinyeka et al., 2016). Tanyanyiwa (2019) confirms that that IKS can be used to guide farming practices, forest resource management, fishing, building, and construction, as well as medicine and pharmacology.

The NOIK shares significant tenets with the NOS, which makes it possible to integrate IKS in science lessons. For example, Zinyeka et al. (2016) found that IKS practices include concepts of plant selection, biodiversity classification and management, and iron smelting. A study conducted by Chitera and Moyo (2021) unveiled concepts such as the cultural technology of building traditional huts, blacksmith skills for making tools from rocks and stones, and traditional beer-brewing methods. Since the NOS and the NOIK can be empirical in nature – the former relying of evidence and the latter relying on experiential and applied knowledge passed from one generation to another – practical work is essential in both systems.

3. Methodology and Context of the Study

This study employed a qualitative exploratory case study that was guided by an interpretivist paradigm. The interpretivist paradigm allowed for the interpretation of the study findings as the subjective experiences and practices of the participants based on their interpretations of their environment (Kivunja & Kuyini, 2017). The study was conducted with teachers in the Harry Gwala education district in the province of KwaZulu-Natal in South Africa. The school sites were located in rural and farming areas, where IKS were applied and formed part of the people’s lives. At the time of data collection, the Harry Gwala district was extremely diverse in terms of culture and ethnicity. It is located near the border of Lesotho and South Africa; the towns of uMzimkhulu and Kokstad were formally part of the South African province of Eastern Cape. Consequently, the majority of the learners were drawn from the Zulu, Xhosa and Sotho cultures. This had implications for the content of IKS taught in lessons, as learners were drawn from these diverse cultural backgrounds.

Participants of the Study

Three teachers, who were assigned pseudonyms, SAT, SBT and SCT, and who had taught Grades 7–9 natural sciences for more than five years and originated from the area, were purposively selected. In addition, two natural sciences Harry Gwala district officials were purposively selected to participate in this study; they were assigned the pseudonyms NSDO1 and NSDO2. The purposively selected participants had experience of integrating IKS practices when facilitating natural sciences practical work and they were, therefore, sources of rich data. Table 1 summarizes the biographical data of the five participants.

Table 1: Summary of the participants' biographical data

Participant ID	Gender	Teaching experience	Teaching subjects	Grades
Natural sciences district official 1 (NSDO1)	Male	9 years	Natural sciences and technology Natural sciences	4–6 7–9
Natural sciences district official 2 (NSDO2)	Male	23 years	Natural sciences and technology Natural sciences	4–6 7–9
School A teacher (SAT)	Female	6 years	Natural sciences Life sciences	7–9 10–12
School B teacher (SBT)	Female	5 years	Natural sciences Agricultural sciences	9 11
School C teacher (SCT)	Female	16 years	English Natural sciences Social sciences	5 7 7

The participants were two men and three women. Three of the participants had experience of teaching in both primary and secondary schools, while two participants had taught in secondary schools only.

Data Collection

Data were collected during the first school term of 2021 through semistructured interviews with the three teachers, one lesson observation with each teacher, and a focus group interview with the three teachers and the two district officials. The questions that were asked during the semistructured interviews and the focus group interviews were meant for the participants to (1) identify the IKS practices they integrated in their science lessons; (2) identify the science topics under which the IKS practices were taught; (3) identify the scientific concepts that were manifest in the IKS practices; (4) identify the applications of the IKS in real life; and (5) identify the practical work activities conducted in lessons to demonstrate the IKS practices. The lesson observations served to collect data on the practical work activities that were undertaken to demonstrate the IKS practices that were used to teach science concepts.

Data Analysis
The data collected were documented as transcripts, which the researchers read several times to familiarize themselves with the emerging concepts. Thematic content analysis was used to analyze the qualitative data collected. Inductive coding techniques were used to identify the themes that emerged from the data. The codes described the IKS, which were verified by linking them to related science topics. The codes were grouped further in larger themes. Table 2 shows an example of the codes of IKS practices that were identified, the related science topics and the three emerging themes that were identified.

Table 2: Example of coding and development of themes

IKS practice codes	Related science topic/CAPS natural sciences knowledge strand	Emerging theme
Home building (mud and grass houses)	Properties of materials/Matter and materials	IKS as an applied science
Building fire with firewood and cow dung	Energy sources/ Energy and Change	IKS as an applied science
Home remedies	Neutralization reactions/Matter and materials	IKS as an applied science
Uses of locally found stones	Properties of materials/Matter and materials	IKS as an applied science
Brewing of traditional beer	Fermentation separation techniques/Matter and materials	IKS as an applied science
Observing the moon cycle	Prediction of the weather/Planet earth and beyond	Use of IKS to understand the environment
Observing the sounds made by animals and birds	Estimation of time and the time of the year/Planet earth and beyond	Use of IKS to understand the environment
Naming the months of the year based the behavior of animals, weather conditions and plant reproduction cycle	Seasons of the year/Planet earth and beyond	Use of IKS to understand the environment
Observation of human physical features	Genetics and variation, human reproduction and puberty/Life and living	Use of IKS to understand the human body, plants and animals
Indigenous agricultural practices	Animal and plant breeding/Life and living	Use of IKS to understand the human body, plants and animals

The selected IKS practices could be linked to science topics and the four knowledge strands of the Grades 7–9 natural sciences curricula.

Trustworthiness of the study and ethical considerations
The ethical clearance to conduct this study was obtained from the University of the Free in South Africa. Informed consent to participate in the study was solicited from the participants. Confidentiality was ensured by concealing the participants' identities. The trustworthiness of the findings was enabled by the use of purposive sampling of participants who integrated IKS in the classrooms. In addition, three data collection tools were used to enable triangulation of the emerging findings.

4. Results and Discussion

The results of the study are presented under three themes, which are (1) indigenous knowledge systems as an applied science; (2) use of indigenous knowledge systems to understand the environment; and (3) understanding genetic variation in plants and animals and the human body development (see Table 2).

Theme 1: Indigenous Knowledge Systems as an Applied Science
This subtheme is based on generation-specific wisdom and practices of local people in their daily activities in their environments. Siambombe et al. (2018) confirm that IKS are developed by groups of people as they go about their day-to-day lives. The concepts under this theme are home building and survival, indigenous agricultural practices, human dependence on nature, and traditional practices.

Home Building and Properties of Materials
This category captures various concepts that were reported as familiar to the learners concerning how their homes had been built, as well as general survival practices. The local houses were built using local materials. The materials were selected based on their properties. Handayami (2018) asserts that IKS incorporate comprehensive knowledge and technologies that are used for survival and problem-solving. SAT described how local structures were built using local materials, including their benefits. SAT said,

> *By looking at the learners' homes that are thatched and made of sunbaked mud bricks. These huts are cool in summer and warm in winter. These traditional huts are used for storage and lounges. (SAT)*

SCT compared the way traditional huts and corrugated iron shacks were constructed, by stating that, in winter, the former is warm and the latter cold. She also described how people stay warm at home. SCT said,

> *Talk about their homes in terms of insulation and how they keep their homes warm. By making learners note that most of the local shop's metallic roofs are painted green. This is because green absorbs radiant heat from the sun; thus, less energy is needed for heating in winter. (SCT)*

Local people build houses and roof them with corrugated iron sheets that are painted immediately after installation. SBT explained that painting iron roofs and gates is associated with a superstition about the *tokoloshe* [goblin], and *inkanyamba* [tornado] in summer. A tornado was believed to be a snake with many heads. In this case, IKS incorporate myths and superstitions caused by illusions of cause and effect (Griffiths et al. 2019). SBT said,

> *Where I come from, there is a belief that during the period of tropical cyclones, it helps. There is a belief in* inkanyamba *[a snake with many heads]. If the corrugated roof is unpainted, it is still shiny and it will attract* inkanyamba. *If the roof is painted green, the* inkanyamba *will pass. Roof painting is mostly related to rust prevention, not the story of* inkanyamba. (SBT)

The IKS practices for building homes illustrate how knowledge of properties of materials was applied. The belief that leaving iron roofing sheets unpainted would attract tornados may have been a superstition, but painting would prevent rust. This is an example of culture-specific superstition; Moore and Nesterova (2020) confirm that IKS are part of the identities of groups of people. The knowledge aligned with knowledge included in the two Grades 7–9 natural science curriculum strands of matter and materials, and energy and change. The selected materials were good for keeping the house warm in winter and keeping it cool in hot weather. El Yazidi and Rijal (2024) confirm that the teaching of IKS in science lessons enriches the learning experience, by providing examples of practical solutions to real-life problems.

Fire and Sources of Energy

The area where this study was conducted experienced very cold weather in winter. Local people had traditional methods of building fires to keep their homes warm. Participants shared IKS practices that linked with natural sciences practical work related to sources of energy and various methods of heat transfer. The practical work involved hand-on activities that can be undertaken by learners, both at home and at school. The methods of heating linked with the topic of heat transfer in the South African Grades 7–9 natural sciences curriculum, thereby linking IKS to learners' everyday lives (Mudaly & Ismail, 2013; Photo & McKnight, 2024). SAT provided an explanation of how fire was made by using sticks and concept of the sources of energy. SAT said,

> *Elders could make fire by rubbing two pieces of wood, by making a small hole in the piece of wood and then rub it with another sharp stick until the wood started smoking, and then dry grass would be used to catch the sparks to start the fire. This will demonstrate the friction and its impact related to energy transfer. Learners observe the burning of wood they use to make fire at home. This wood is used once; it burns completely and gives off ash and bits of charcoal that cannot be reused to make fire again. The formation of the ash can be explained to learners as energy has been used up completely.* (SAT)

The participating natural sciences teachers discussed the various materials used by local people to build fires. SCT worked at a farm school and lived in a farmhouse. She discussed how they kept warm in winter.

> *Local people make fire using dried cow dung, mealie cobs and at school we use these. All these are biofuels. Traditionally the firebase is made at the center of the house but in our situation all the fireplaces were built against*

the wall on the corner. The fire base is placed at the center so that the convection currents warmed the whole house. (SCT)

SBT concluded by stating that these concepts are used in the demonstration and practical work related to heat transfer. SBT said,

The concept of heat transfer that is taught to learners is that when they make fire in the fire base at home heat radiates in all directions in of the house. (SBT)

The participating teachers discussed how solar energy was used locally to recharge old batteries and heat water for bathing. SBT discussed the use of solar energy to charge solar batteries people used for lighting at home. SBT said,

They rely on the sun to save on prepaid electricity, by placing depleted, vintage Eveready transistor batteries in the sun and reuse. Some of the households still have solar batteries that they installed before they got electricity from the municipality. (SBT)

SCT discussed how a practical example to demonstrate solar radiation and absorption by materials was evidenced in the community. SCT said,

I went to a house which is not on a farm but in some deep rural area around. They had painted their Jojo [water tank] black, with the belief that black absorbs more heat and warms the water inside the tank. So, they use the water in the black tank to bath. (SCT)

This practice of heating water is related to the topic of energy sources in the natural sciences curriculum; the fireplace in households can be used as a practical example to show methods of heat transfer, such as the many applications of the energy from the sun for demonstrating and investigating solar heat transfer via radiation.

Local Remedies, Catalysts, and Neutralization Reactions

Local people have long survived by eating foods that take a long time to cook; these foods, which include dried beans, crushed corn kernels, and tripe, are known for causing heartburn and diarrhea. To solve these problems, local people found ways to cook these foods faster and to ensure that they are tender. SBT and SCT discussed local cooking methods, and ways of treating heartburn. According to SBT, local people cook foods faster and make them tender by adding *umuthi kamingi* [bicarbonate of soda] as a tenderizer. The people also believed that bicarbonate of soda can treat diarrhea, though it is mostly used to treat heartburn. SBT said,

When cooking samp *[maize rice] and tripe we use to add bicarbonate of soda as a tenderizer/catalyst so that the food gets cooked very quickly. We also use bicarbonate of soda for a running stomach and heartburn. The bicarbonate of soda has a local name they call it* umuthi kamingi *in isiZulu [one of the languages in South Africa].* (SBT)

In the science classrooms, the action of bicarbonate of soda can be related to the concept of catalysts in chemical reactions, as it shortens the cooking time of samp. As it also treats heartburn, it also acts as an antacid and the concept is relevant when teaching neutralization reactions under the topic of acids and bases. Similarly, SCT explained how local people drink water mixed with ash from a fire made of wood from black wattle trees to treat acid reflux. The ash was a substitute for the bicarbonate of soda. SCT said,

> *At home they use fire to keep warm and this fire produces ash. This ash has multiple uses: to brush teeth and taken when someone is suffering with acid reflux.* (SCT)

SBT was observed discussing the basic properties of ash with learners at School B. The discussion is contained in the extract from the lesson observation transcript.

> *SBT: We also have our own local and traditional bases like ash that is normally used in our homes. What do we use ash for?*
> *Learner B1: It is used to treat ingestion and heartburn.*
> *SBT: What else, like in the garden?*
> *Learner B2: We throw it in the garden to improve the soil fertility.*

The discussion shows how ash collected from the fireplaces could be used to neutralize conditions of acidity encountered in the learners' everyday lives. The ash was also used as medicine to treat some conditions caused by acidity. Abah et al. (2015), Zinyeka et al. (2016) and Tanyanyiwa (2019) confirm that some of the IKS resonate with areas of medicine and pharmacology.

Uses of Rocks

Local elders knew about rock types and their uses. This knowledge aligns with the strand of matter and materials in the Grades 7–9 natural sciences curriculum in South Africa. This knowledge is used by blacksmiths when they use rocks to develop tools such as grinding stones that are used to crush grains into flour (Chitera & Moyo, 2021). SAT shared how local people had various uses for rocks.

> *There is a certain kind of stone that was used to grind and mix herbs [*imbokodo*] with a smooth round shape for easy hold. This can be integrated in science teaching to introduce the types of rocks and their daily uses. Another thing, learners will have to look at the stones used to fix the gravel roads locally. Normally, the contractors will get sediments from the local quarry. These types can easily be broken by car tires. (SAT)*

SBT explained how local people used sedimentary rocks:

> *Sedimentary rocks are those rocks that are compacted, we use those rocks, but we call them* ukhethe, *to make* umthangala *[retaining wall]. This is done when the yard is steep, to make it even. It also helps to prevent erosion. This soft rock is also crushed into powder and mixed with water to paint the traditional huts as they also have the same color with the mud used as a plaster.* (SBT)

These IKS can be linked to the topic of the lithosphere, and learners can be asked to differentiate between types of rocks and stones used at home. The teacher can introduce the different rock types based on the various types of rocks learners discussed in class.

Brewing of Traditional Beer, Separation of Mixtures
Traditional beer making is part of every indigenous African community. The participants discussed how the traditional beer-making process is relevant to science practical work activities. These activities helped the teachers to bridge the gap between scientific concepts and the lived experiences of the learners (Bossér, 2024). NSDO1 explained how, during the COVID-19 lockdown period, when the sale of beer was banned in South Africa, people prepared alcohol substitutes and made a local illegal brew they dubbed *ifruit*. NSDO1 said,

> *During the nationwide lockdown people were making their own alcohol. They bought grapefruit from the local shop; they had ways to turn it into alcoholic drinks. They mixed the grapefruit with sugar and sealed the mixture. This had to stay for five days, and it was ready to drink.* (NSDO1)

NSDO1 added that the home-made brew came out clear after the brewing and straining process: "This mixture came out clear like water." In the lesson that SBT was observed teaching, the learners conducted a practical work activity where they used filtration to separate clear tea made of the tea bush (*rooibos*) endemic to South Africa, as shown in Figure 1.

Figure 1: Learners using filtration to strain *rooibos* tea

Traditional beer brewing and tea brewing using dried and crushed leaves such as that of the *rooibos* bush is a practice that can be used to introduce the topic of mixtures and the physical separation of the various mixtures. Locally, traditional beer was strained by physical methods, such as using a traditional strainer and a sieve.

The IKS practices that were identified as applied science were cultural technologies for building houses, application of neutralization and fermentation reactions, separation of mixtures, energy and fuels and the concepts of heat transfer. Similarly, Chitera and Moyo (2021) identify the technologies in construction, blacksmith skills and beer brewing to be some of the practices inherent in IKS.

Theme 2: Use of Indigenous Knowledge Systems to Understand the Environment

IKS concepts were also used to explain events that occur in nature. These explanations and predictions are based on observations of nature over time. Barnhardt and Oscar Kawagley (2005) confirm that IKS can be developed through empirical observations of natural phenomena. This theme explored how IKS explained how the people depended on the observations they made to understand nature and their immediate environment.

Human Dependence on Nature and Indigenous Knowledge

In the past, people had no clocks, and they relied on observing nature to estimate the time; they still do this today. Participants explained how people related to and depended on nature for their survival. NSDO1 explained how a month was calibrated using moon cycles:

> *Elders used the period of a moon cycle to the next full moon to calibrate a month cycle period, but they had no dates.* [NSDO1]

SBT gave a detailed explanation of how the moon phases are used. According to SBT, the various moon phases are used to explain and predict the winds and the full moon in winter was used to explain windy conditions:

> *The full moon is also used to predict or determine a weather situation for that short period of time. Something was related to the weather when its full moon. When its windy at a certain time they will say it's because of the full moon.* [SBT]

Local people have ways to estimate different times of the day. The behavior of domestic animals also indicated the time of day: the time they wake up in the early morning, the hourly intervals, and seasonal changes. NSDO2 said, "The elders relied on the sound of the rooster to wake up in the morning."

SAT shared how local people relied on sounds of domestic animals to determine hourly intervals, the movement of the shadow of a traditional hut against the position of the sun, and the wailing of a certain bird around December to tell the time of the year. SAT said,

> *The sound of the braying donkey is related to hourly intervals, as it brays hourly. At home there is a certain bird the Cape longclaw, which wails, signaling the approaching of Christmas. Elders interpret the sounds made by the animals to signify the time of the year because that certain bird sound is only heard around the festive season. Soon after they will ask their grandchildren when is the Christmas day? This bird's cry also signaled to the elders that it's time to start planting crops. They used to say the wailing sound says* phezukomkhono *[roll up your sleeves]. For them, this meant they should carry hoes on their shoulders and go to the fields.* [SAT]

Changes in vegetation have great significance for local people, as the months of the year are named according to vegetation changes. SBT and NSDO1 discussed a few months of the year, and the vegetation conditions related to those months. NSDO1 said, *The months of the year in isiZulu were named according to vegetation changes throughout the year. [NSDO1]*

SBT described the months of the year in detail, naming them in isiZulu and explaining the vegetation conditions for each month:

August – uNcwaba – vegetation is ready to grow new leaves; grasses are slowly showing signs of growing green. September – Mandulo – vegetation grows green after getting the last rains of winter called imbozisamahlanga*; December – uZibandlela – the local or traditional paths are covered with tall green grass. February – uNhlolanja – mating season for dogs that signals we are nearing the end of summer; May – uMbasa fire season; June – uNhlaba aloe blooms and then July – uNtulikazi – when it's mostly windy.* [SBT]

In the farmstead context, SCT mentioned that people mostly depended on seasonal farming activities. SCT said,

The estimation of seasons, whereby they look at nature as it changes with seasons. In the local farmstead, they knew the planting season and when they were going to get more rains. Hay grows faster and they are cutting it for storage to be used in winter the next year stored as bales to feed livestock. Learners observe the sunrise and sunset pattern and align their comparisons with the seasons. [SCT]

SAT explained how elders estimated time intervals during the day. They watched the position of the sun, and the anticlockwise movement of shade around the huts:

Elderly people in rural areas use the position of the sun and the human shadow and can tell if the sun is up in the sky on top of their heads, its midday. They also use the movement of the shadow of the traditional, as it moves around the hut in anticlockwise direction. [SAT]

In some IKS practices mentioned by the participants, the use of observations and gathering of data in order to reach conclusions about natural phenomena and the use of that data to make decisions was evident. The practice observations and use of data to make inferences is inherent to science practical work (Akuma & Callagan, 2019a). There were ways to observe nature to tell the time day of day and what time of year it is. The data are also used to predict weather conditions. Zinyeka et al. (2016) observed that IKS was used to explain meteorological and climatic events. Lipe (2023) shows that IKS are holistic and transdisciplinary because the observations made and data collected about nature were used to inform human activities during the day and throughout the year.

Theme 3: Understanding Genetic Variation in Plants and Animals and the Human Body Development

Local people had their own traditions and social practices that were part of their lives. When a child is born, the elders performed a traditional paternity ritual. As children developed physically, they participated in a coming-of-age ceremony to mark the milestone. While Zinyeka et al. (2016) found that IKS also included topics such as plant diversity and biodiversity, in this study we found that IKS could also be used to explain genetics and traits of human beings.

Physical Features and Variation

Elders were skilled at observing common family physical features and other qualities, and this skill was used to verify the paternity of newborn children. NSDO2, SAT, SBT, and SCT discussed the main features the elderly women focused on and how this practice of traditional paternity denied paternity to children with undesirable traits. This may be a case where erroneous beliefs that do not align with explanations based on science (Bantubilli et al., 2022; Nyhan, 2020). NSDO2 explained that elderly women claimed to know family features and their variations within a family. NSDO2 said,

> *Female elders are very good at identifying common family features. Their main key was hands and feet. They could see the family traits variation and something about the lines in the palm of their hands.* [NSDO2]

SCT mentioned how a traditional paternity custom was used to confirm or deny the paternity of a newborn or infant child. However, SCT warned that this custom was flawed, as paternity was often denied if a child had a physical disability or was born with albinism, based on a belief that these undesirable conditions did not exist in the family. SCT said,

> *The child was brought into the family so that the family elders will look at the child using physical features that are common in the family to confirm paternity of that child. But in some cases, children with albinism or with physical disabilities were mostly denied paternity as the families do not believe that in their family such a child could exist.* [SCT]

SAT explained how elders determined the paternity of a child:

> *For elders to confirm paternity it was not about the skin color. At birth they will look at the feet or even look at the front part of gums and tell that the child will have a diastema.* [SAT]

The traditional practices of confirming paternity, according to SBT, can be used to connect to the concept of active and inactive genes in a family:

> *Denying paternity for a child relates to not understanding the concept of active and inactive genes in the family. In some cases, you will find that someone in the older generation had these features.* [SBT]

SAT suggested that misconceptions can be cleared up when the topic of genetics is discussed in Grade 9. SAT said,

> *Children inherit these features from their parents: the shape of the feet, the toe shape and heels including the lines in the palms of hands. Then at Grade 9, introduce the genetics and inheritance of these family features.* [SAT]

Physical Features and Puberty

The coming-of-age ceremony [*umhlonyane*] was one of the very important cultural practices of the local people in Harry Gwala district. This was held by elders when a girl child reached a certain age based on the child's physical development. The most observed physical changes are height and body size. SBT and SCT discussed this cultural practice. SBT explained how elders observed the children in the family and noted their physical development. SBT said,

> *Our elders look at the physical changes girls experience as they grow. They will look at a girl child and see that the breasts are developing, and then they will know they have to observe the coming-of-age rituals like* umhlonyane *[passage into adulthood].* [SBT]

SCT shared the same view and said,

> *In their homes, elders know about a local coming-of-age ceremony [*umhlonyane*]. This is done for young girls when they enter puberty, locally called* ukuthomba. [SCT]

These IKS practices were relevant to the teaching of the science topic of puberty, and the learners' experiences and prior knowledge could be referenced by the teachers.

Indigenous Agricultural Practices and Physical Properties

Local people were subsistence farmers. SBT explained that local learners are exposed to traditional interbreeding of animals, a local concept called *ukutsita*, which includes seed selection and harvesting. SBT said,

> *Elders breed animals based on the physical traits of those animals by allowing them to inter-mate thus to breed animals or offsprings that are stronger and resistant to certain disease. Even for plants, if the harvest is desirable commonly maize with a large cob or grains, and well grown. This will be kept safe after harvesting and will be used for the next planting season. This originates from observing the physical traits of the harvest.* [SBT]

In exploring the IKS practices that were integrated in the Grades 7–9 natural sciences practical work in the South African curriculum, the findings of this study show some ways in which this could be done. The integration was possible because the participants could select certain IKS practices that could fall under the four knowledge strands of life and living, matter and materials, energy and change, and earth and beyond of the natural sciences curriculum. The IKS aligned with natural sciences practical work through the teaching of applied science and technology (Chitera & Moyo, 2021; Mpofu & Vhurumuku, 2017; Wilujeng & Prasetyo, 2018) and use of empirical observations to make inferences (Barnhardt & Oscar Kawagley, 2005). However, some of the IKS concepts were mixed with myths and beliefs that were not scientific (Bantubilli et al., 2022; Griffiths et al., 2019; Nyhan, 2020).

5. Conclusion

Three major findings were made in this study on how IKS could be integrated in science practical work. The first finding showed IKS were understood as an applied science in which knowledge was used to solve real-life problems. The IKS were taught as lived experiences of everyday life activities, thereby demonstrating a holistic, transdisciplinary and contextual nature (Barnhardt & Oscar Kawagley, 2005; Lipe, 2023). The practical applications of IKS as taught under the different science topics helped to bridge the gap between what is learned in the classrooms and the learners' real-life experiences (Bossér, 2024; Mudaly & Ismail, 2013; Photo & McKnight, 2024). The IKS were used to determine materials to build houses as homesteads, to select local stones to make tools, select natural materials with basic properties to treat ailments and tenderize food, separate mixtures when preparing beverages such as traditional beer and tea made from the endemic *rooibos* bush, and using biofuels to make fire for household needs. These IKS align with the notion that indigenous practices incorporate local technologies (Chitera & Moyo, 2021; Mpofu & Vhurumuku, 2017).

The second finding showed the role of observation and data collection for decision-making when integrating IKS, which aligns with the empirical nature of science practical work. IKS are also based on empirical observations (Barnhardt & Oscar Kawagley, 2005). By using observations of the natural world, the data collected were used to understand the environment, the development of the human body and genetic traits, and variations in plants and animals. The data collected from the observations were used to determine when and how to conduct day-to-day, cultural and agricultural activities, for example, using moon cycles to predict the weather and start and end of a month, using animal sounds to determine time intervals and the time of year, and referring to changes in the vegetation to determine the month of the year.

The third finding is that some of the IKS were spiked with myths and superstitions that resulted in decisions that were not consistent with scientific facts (Bantubili et al., 2022; Griffiths et al. 2019; Nyhan, 2020). Myths and superstitions help to persuade people to take part in cultural activities and, thereby, forge group identities. Based on this finding, the study recommends that, in instances where myths and superstitions are involved, teachers need to incorporate the teaching the NOIK and the NOS to help learners identify distorted views of science. Additionally, teachers need professional development support to manage the cultural diversity of IKS that can be incorporated in the science classrooms. Future research studies are recommended to explore the influence of learner diversity and multiculturalism on the teaching of IKS in science classrooms.

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7. References

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