**South African Journal of Childhood Education**
ISSN: (Online) 2223-7682, (Print) 2223-7674



# Teaching science in the foundation phase: Where are the gaps and how are they accounted for?

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**Dates:**
Received: 06 Apr. 2019
Accepted: 24 Aug. 2019
Published: 18 Nov. 2019

**How to cite this article:**
James, A.A., Beni, S. & Stears, M., 2019, 'Teaching science in the foundation phase: Where are the gaps and how are they accounted for?', *South African Journal of Childhood Education* 9(1), a759. https://doi.org/10.4102/sajce.v9i1.759





**Background:** Foundation phase teachers are not science specialists; however, they are expected to teach science. It is important that research determines where teachers face challenges in teaching science in order to assist them to bridge the gaps and to improve their competence in teaching science.

**Aim:** The aim of this research was to explore teachers' implementation of the science curriculum.

**Setting:** The research was conducted in a primary school in a province of South Africa. Four foundation phase teachers participated in the study.

**Methods:** This interpretative, qualitative study used classroom observation, learners' workbooks and post-observation interviews to develop an understanding of teachers' science knowledge, their facilitation of hands-on science investigations as well as the nature of their interaction with learners in the science classroom.

**Results:** The findings revealed that teachers were not competent in teaching science and when rated according to their profiles of curriculum implementation all four were allocated low scores. However, in-depth observations revealed that while teachers generally had poor science knowledge, they were competent in engaging learners through questions and activities. This pedagogic knowledge could have translated into pedagogic content knowledge should the teachers have attempted to spend more time preparing their science lessons to ensure that they mastered the necessary science content and science knowledge, as well as appropriate methodologies to teach science.

**Conclusion:** Science education should be in the foreground in the foundation phase curriculum to encourage teachers to teach science as an integral part of the curriculum.

**Keywords:** classroom interaction; hands-on science; implementation; science curriculum; science knowledge.

## Introduction

Since 1994, Early Childhood Development (ECD) has been acknowledged and recognised as an essential focus theme for South Africa's social and economic transformation and development (South African Department of Basic Education 2009:11). The current curriculum in post-apartheid South Africa is known as the Curriculum and Assessment Policy Statement (CAPS) (South African Department of Basic Education 2011). In this curriculum, natural science as an area of learning is included as a component of 'beginning knowledge'. Unfortunately, little emphasis is placed on natural science learning.

Previous research by Beni, Stears and James (2017) reported on the way in which foundation phase teachers interpreted the curriculum to enable them to teach natural science. Their study found that the biggest challenge for teachers was the poor guidance received from the curriculum as to what and how they should teach natural science. Content topics were not specified, neither were possible instructional methods suggested in the curriculum. In the light of these findings, further research focused on how science teaching unfolded in the classroom.

Engagement with science in the early years may act as a catalyst in developing learners' interest in science in later years. In doing so, it could supply learners with opportunities to expand their inherent curiosity about the natural world (Rocard et al. 2007), enabling the acquisition of knowledge, skills and values which will form the basis of their future learning (Sackes et al. 2010). Yet, science is not always the priority in primary schools as one may expect (Campbell & Chittleborough 2014). It has been suggested that improved resources, more time spent engaging

in science activities and better science teaching are needed to remedy the situation (Australian Council of Learned Academies 2013). Petre (2013) maintains that using appropriate teaching instructional methods and resources may contribute to developing and maintaining a constructive association between the learners and their natural environment. The importance of effective primary science teaching particularly in the foundation phase cannot be underestimated.

At the foundation phase level, the teacher's role is crucial in teaching learners the foundational knowledge and providing opportunities for them to develop the appropriate skills linked to numeracy, literacy and life skills. The claim that primary school teachers are normally hesitant to teach science (Appleton 2008; Tytler 2007) is discouraging. Further research provides two reasons for this claim: limited knowledge of science content and a limited science pedagogical content knowledge (Appleton 2008; Fleer 2009). Most foundation phase teachers face the challenge of teaching all or most subjects offered in that phase and within the subject of science, they face the further challenge of teaching all the specialisations within science. Furthermore, they are expected to teach these by facilitating appropriate scientific practices (Davis & Smithey 2009). The depth of subject content knowledge may also affect the ability of the teacher to ask meaningful and appropriate questions. Research conducted in schools has identified the fact that science teaching is challenging with teachers either depending on a 'specialist' teacher to teach science lessons or avoiding science teaching because of feelings of inadequacy in themselves as teachers of science (Buxton 2010; Tytler 2009). All these factors contribute to early childhood classrooms not offering high-quality science experiences for young children. High-quality science education is important in laying the foundation for children's knowledge and interest in science (Gerde, Schachter & Wasik 2013).

It is generally agreed that an important approach in science education is inquiry-based learning where learners are actively engaged in 'hands-on' science activities (Ergül et al. 2011; Rocard et al. 2007). With foundation phase learners, 'doing science' may be achieved by conducting scientific investigations on natural phenomena. Opportunities should be created for learners to ask questions, to carry out investigations and to solve problems. There is also a social context to doing investigations as the learners discuss and share new ideas (Pappas & Tepe 2002). Trundle (2015) is of the view that this type of approach will facilitate the development of foundational knowledge and skills for life-long learning as well as an appreciation of nature. While children's curiosity, asking questions and exploration develop spontaneously, the development of process skills require support and instruction from adults to develop into the process skills seen in scientifically literate scientists (Jirout & Zimmerman 2015). However, Murphy, Varley and Veale (2012) are of the view that while many of the learners in their study were optimistic about learning science, using hands-on inquiry and group work, not all learners felt inclined to engage in hands-on activities. To engage all learners would require special skills from the teacher. Van Aalderen-Smeets, Van Der Molen and Asma (2012:161) reiterate that it is critical for 'foundation phase teachers to extend their own positive attitudes towards science if continuous progress in primary science education is to be attained'. Although learners are given opportunities to carry out experiments and participate in hands-on science, frequently these practices are inclined to be teacher rather than pupil focussed (De Boo & Randall 2001; Department of Education for Northern Ireland 2002). Andrée (2012) considered how changing the circumstances of classroom activities could increase learners' participation in science learning.

Alexander (2001:394) maintains, 'it is now generally accepted that cognitively demanding interaction is a fundamental condition for all successful teaching of young children, however it is organised'. This is supported by Johnston (2005) who maintains that child-centred experiences are essential for greater scientific development. For significant social interaction between the teacher and learner in the context of teaching to occur, there needs to be a mutual respect between teacher and learner (Hayes et al. 2006).

The purpose of this research was to determine teachers' competence in implementing the science curriculum. Rogan and Grayson's (2003) theory of implementation provided a framework for this phase of the research. This framework places teachers on one of four possible levels for each of a number of constructs pertaining to science teaching. This enabled us to categorise each teacher's implementation of the natural science curriculum. It was important to identify where the teachers' strengths and weaknesses lay rather than just assuming that their science knowledge was deficient.

Rogan and Grayson's (2003) model uses a number of constructs to determine a teacher's ability to implement an innovative science curriculum. In this report, we adapted the model to include three sub-constructs which we linked to one main construct, the profile of implementation, which formed the framework for the study. These sub-constructs are science knowledge, classroom interaction and 'hands-on practicals or scientific investigations'. Each teacher's profile for each sub-construct was then determined based on the findings. Figure 1 represents the adapted model.

The following three questions framed the research:

- What is the level of foundation teachers' understanding of science content and concepts?
- How do foundation teachers facilitate hands-on learning or scientific investigations?
- How do foundation teachers manage classroom interaction during natural science lessons?

Teachers chose their own content, which post-observation interviews revealed were mostly determined by what was

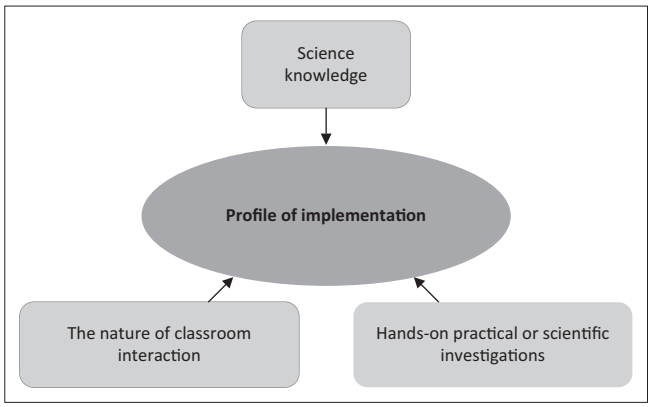


**FIGURE 1:** Framework adapted from Rogan and Grayson's (2003) model in Rogan (2007:99).

taught in the previous year. There appeared to be a number of topics that were taught every year, for example insects, the weather and my body, with very little new content introduced. Hands-on learning refers to any practical activities related to science learning, whereas scientific investigations refer to structured activities where learners investigated a problem. Classroom interaction considered the relationship between the teacher and the learners in the classroom setting with regard to the lesson structure, learners' attentiveness, questioning, use of resources and types of activities learners engaged in.

# Methodology

This research is located in an interpretive qualitative paradigm. It explores foundation phase teachers' implementation of the natural science curriculum at a selected school in a province of South Africa. Four foundation phase teachers from Grades R, 1, 2 and 3 participated in this study. The school draws learners from an environment where their parents/guardians are from the working class. Resources in the school are adequate.

The pseudonyms used for the teachers were Karen, Fiona, Carly and Simone. All four participants were assured that all information provided would be treated with the utmost confidentiality. The project was granted ethical clearance by the university.

Teachers were observed for a week and were asked to include science as a component of 'Beginning Knowledge'. Classroom observation (Appendix 1) therefore formed the core of data collection as this provided an in-depth understanding of teacher's knowledge, their facilitation of hands-on science in action and their interaction with learners as well as their facilitation of interaction between learners.

Criteria (Appendix 2) informed by Rogan and Grayson's model for each level of the profile of implementation were used in observing teachers in the classroom. Learners' workbooks (Appendix 3) were analysed to obtain information regarding the stipulated criteria that may not have emerged during the period of observation. Interviews (Appendix 4) were conducted with teachers post-observation to obtain more clarity where necessary. These three data sources provided the triangulation required to confirm that the data were trustworthy. On analysis of the data, a table was constructed for each teacher, placing her at a particular level with regard to the three sub-constructs mentioned above. The criteria used for placing each teacher at this level may be compared to the composite table included as Appendix 2.

## Ethical considerations

The project was granted ethical clearance by the University of KwaZulu-Natal (ethical clearance no. HSS/0922/09D).

# Findings

The findings of this study are presented as narratives of the activities related to science, that the teacher and the learners engaged in during the period of observation in each of the respective classes.

## Science teaching in Karen's Grade R class

Karen taught no science lessons during the week of observation. When she was questioned about this after the lesson observation, she mentioned that she did teach natural science. She said, 'Learners brought in fruits to make a fruit salad. We spoke about the different colour textures'. This topic was taken from a workbook for Grade R learners. She also mentioned an activity which involved learners making jewellery with beads. In an attempt to provide an example of how she used play to teach natural science, Karen provided the following explanation during the interview:

> '[*L*]ike with play … when you come to play, especially with water and ask them the question of what do you use water for and then talk about the different uses of water, I will get them to dirty their hands. I will then get them to use the water to wash their hands so that they can have clean hands.' (Interview, Karen explaining an aspect of her teaching, May 2013)

This response demonstrated Karen's limited knowledge of science concepts.

Analysis of the Grade R learners' books revealed that there was no evidence of hands-on science or scientific investigations in the teaching of natural science as no lesson could be classified as a true science lesson.

Some of the activities observed were interactive in nature and Karen often placed learners in small groups, asked frequent questions and used a number of resources, such as posters, books and worksheets. These attributes could have assisted her to teach science effectively; unfortunately, she chose not to teach science. Karen's class was quite disruptive early in the morning, but she managed to calm them down quickly by diverting their attention to a particular activity like singing songs.

As Karen taught no science during the time she was observed and no science lessons were observed in learners' books, Karen was placed at level 1 for all three sub-constructs (Table 1).

**TABLE 1:** Karen's level with regard to her profile of implementation of three sub-constructs.

| Level | Classroom interaction | Hands-on science and investigations | Knowledge and understanding of science content and concepts |
|---|---|---|---|
| 1 | No interaction with regard to science teaching | No evidence of hands-on science to help develop concepts as no science was taught | Karen did not teach a science lesson but the interview demonstrated limited knowledge of science |

## Science teaching in Fiona's Grade 1 class

Fiona did not focus on one theme during the week of observation, although 'weather' was a daily topic of discussion. While learners were asked on the first day to look out and observe the weather, this was an isolated incident and there was no evidence of any structured observations over the remaining days. There was some reference to what made kites fly and the fact that leaves of trees were green in spring, but no evidence that learners were taught any science concepts. During the discussion on spring, Fiona told the learners that the flowers start to bloom, the trees start bearing fruit and the butterflies come out. She informed them that 'there are insects that come out, for example the caterpillar, ladybirds, bees'. She then changed the subject by saying 'Bees make honey'. Extract from observation schedule: Fiona posing questions to her Grade 1 class, 'How do bees make honey?' She gave the learners a short explanation without probing their prior knowledge.

Most of the activities that the learners participated in were discussion activities either with the whole class or in smaller groups. During one of the lessons, Fiona had a bucket of muddy water which she showed to the learners. She told them that besides the leaves that were in the water there was also 'bacteria and germs'. She explained that when water stood for long it had a bad smell. When Fiona asked the class what they could get from playing in the dirty water, a learner said you could get ringworms from playing in dirty water. Fiona did not correct this misconception. All she said was that they could also get a rash on their skin, which could become pimples.

Fiona then showed the class a bucket of clean water and another bucket with dirty water. She asked the class which water they would rather play in. She made the learners smell the two types of water. Fiona asked the class which water they would use to wash their hands. Fiona took the bucket around to the learners. She asked the learners what colour the water was in the pond near the school. The learners said that the water was green. She told the learners that the water was very unhealthy and if they played in the water, they would get bilharzia.

Fiona then instructed the learners to draw two pictures: one showing dirty water and the other showing clean water. However, she continued asking the learners questions. She asked, 'Which water would the fish live in?' One learner pointed to the dirty water. She asked the learners to identify what people threw in dirty water. Fiona then asked if they should throw all those things in the water and what effect this would have on the fish in the rivers. She explained that the fish will not be able to breathe and it will kill the fish because they will not be able to come up from the water for oxygen. Extract from observation schedule: Fiona providing information to her Grade 1 class, 'Fish swim and swim and then they come up for oxygen'.

On the following day, Fiona placed a chart on the chalkboard depicting hygiene and water. Fiona asked the learners to identify actions that were wrong in the picture. There were people washing clothes alongside the river and using the river as a toilet. Learners compared the two pictures and identified actions that were good and actions that were bad. Fiona presented the learners with a scenario:

> 'If you were near a river and you were very thirsty what would you do to make the water safe for drinking? What must your mum do to the water to make it safe for you to drink?' (Extract from observation schedule: Fiona teaching her Grade 1 class, May 2013)

The topics covered in Fiona's class were covered every year. The science aspects were quite basic and with a little research, Fiona could have ensured that her facts were correct. Better understanding of the science would have allowed her to present lessons that were more coherent.

There was no evidence of hands-on science or investigations indicated in the learners' books either. However, during the post-interview, Fiona explained with the following example how she used 'hands-on' instructional methodology to teach natural science:

> 'The different seasons where we dress up the children in summer wear, winter wear and autumn. For autumn, we bring in the kite. Because autumn is not so clear and distinct. For spring, we bring some flowers or any greenery. We also dress them up like summer. We teach them that every season has three months … it starts in December. If the day is cold, we are going to stay inside. They know in winter the days are shorter and the nights are longer. They can tell you that.' (Extract from observation schedule: Fiona teaching her Grade 1 class, May 2013)

Although the example with the clean and dirty water could relate somewhat to a science lesson, as the topic of pollution was touched on, for the most part this was a life orientation lesson as the main focus was on health issues. The topic of insects came up during one of the daily discussion session on seasons. The discussion was short and not much content knowledge on bees and honey was mentioned to the learners to constitute a science lesson.

Table 2 shows the levels for the three sub-constructs used to determine Fiona's profile of implementation with regard to natural science teaching. Fiona was placed at level 1 for hands-on science and scientific investigations as there was no evidence of this. The number of science misconceptions held placed her at level 1 as well. Although she tended to answer her own questions, she did allow learners some limited discussion of questions she posed and engaged them in an activity related to pollution. This placed her at level 2 for classroom interaction (Table 2).

## Science teaching in Carly's Grade 2 class

Carly's lessons for the week focused on insects. However, in her introductory lesson when she announced the theme 'insects', she gave the learners a drawing of a spider to label. She was oblivious of the fact that a spider is not an insect. On the third day, learners were given a worksheet with a diagram of a dragonfly. She read the names of the body parts of insects from a book which learners repeated after her. She proceeded to add labels such as 'feelers', 'harmful' and 'unharmful' to the drawing of the dragonfly and then read from the worksheet. Carly seemed hesitant when learners were calling out the answers. She did not commit to any answer but made the learners count the number of the labels on the worksheet. Carly was uncertain about the responses that the learners gave and kept looking at her response sheet for the answers. She tried to work out the answer before giving them to the learners.

Carly then handed out two worksheets. The one had the diagram of the spider and the other had the labels. She said they were going to label the different parts of the insect: head, thorax, abdomen, wings and feelers (antenna). The learners had to cut out the words and stick them in the correct space. Carly walked around the class cutting the labels for the learners. However, as the spider does not possess such body parts, learners struggled to find the correct parts. Carly assisted learners in adding incorrect labels to body parts.

A chart labelled 'insects' was at the back of the class. Carly asked learners to call out the names of the 'insects' as she pointed to them. This chart included a number of animals, such as snail, frog, scorpion, centipede and spider that are not insects, but Carly was not aware that these animals were not insects. Extract from observation schedule – Carly posing a questions to her Grade 2 class, May 2013:

> 'Where do these insects live?' She then answered her own question, 'Some are found in water (e.g. scorpion), others in plants or flowers (e.g. honeybees on trees), branches (e.g. ladybird), sand (e.g. worms, snails and ant).'

Extract from observation schedule – Carly posing a question to her Grade 2 class, May 2013:

> 'Are all these insects harmful or dangerous?'

While the theme insects did provide opportunities for hands-on science through direct observation and the development of skills, such as comparing and classifying, the focus was on naming insects and labelling body parts. Little interaction occurred between learners; the only interaction was between learners and the teacher as they answered questions.

Although there was no evidence of scientific investigations and hands-on science, there were entries in the learners' life skills book on insects. Most activities related to insect body parts. When asked during the post-observation interview what she understood by hands-on science. Extract from interview transcript – Carly explaining her understanding of hands-on science, May 2013:

> 'Eh … hands on … I can't think of examples now … isn't it things that you can practically do? You know with your hands.'

Carly cited the bean plant activity of hands-on science that she did with her learners. Carly believed it is important to rather use demonstrations at this stage.

Carly's lesson had the potential to facilitate science learning, if only she had made an effort to prepare better and ensure that she knew the science concepts she was going to teach. Her lessons were basically about identifying insects, their main characteristics and the concepts useful and harmful. Unfortunately, her lack of science knowledge prevented her from teaching a meaningful lesson where a learner could learn to distinguish between insects and other animals.

Table 3 shows the levels for the three sub-constructs used to determine Carly's profile of implementation with regard to natural science teaching. The evidence of classroom interaction placed Carly at level 2 as there was some interaction during lessons. She was placed at level 1 for hands-on science or scientific investigations as there was no evidence of this. Her lack of science knowledge placed her at level 1 for this sub-construct as well (Table 3).

## Science teaching in Simone's Grade 3 class

Simone's lessons focused on animals. She wrote the words elephant, giraffe, cow and impala one below the other on the chalkboard next to a picture of different animals. She then asked the learners how many of each kind of animal were in the picture and what types of animals they were. Simone did not appear confident that she actually knew the names of the animals and was happy to accept the children's answers as the correct ones. Simone demonstrated to the learners how to

**TABLE 2:** Fiona's level with regard to her profile of implementation of three sub-constructs.

| Level | Classroom interaction | Hands-on science and investigations | Knowledge and understanding of science content and concepts |
|---|---|---|---|
| 1 | - | No evidence of hands-on science to help develop concepts. Learners were not practically involved in the lesson | Fiona demonstrated poor knowledge of science concepts. A number of misconceptions of learners were not corrected |
| 2 | Fiona asked a number of questions but often answered them herself. Some learners did participate when given the opportunity. Small group discussions were appositive in aspect | - | - |

**TABLE 3:** Carly's level with regard to her profile of implementation of three sub-constructs.

| Level | Classroom interaction | Hands-on science and investigations | Knowledge and understanding of science content and concepts |
|---|---|---|---|
| 1 | - | No evidence of hands-on science to help develop concepts. Learners were not practically involved in the lesson | Carly demonstrated very poor knowledge of science concepts. Many misconceptions emerged during her lessons |
| 2 | Some evidence of involving learners by asking questions and learners were given activities | - | - |

draw a bar graph indicating the numbers of animals. She asked the learners to complete the graph.

Simone then wrote the word 'animals' in the centre of the chalkboard and circled it. Simone asked the learners:

> 'What type of animal is an elephant?' and 'what category of animal is an elephant?' She then went to the chalkboard and drew three arrows from the word animal, saying that there are three kinds of animals. She then asked the class: 'Can you keep an elephant at home in your yard?' They said no. She then asked what type of animal an elephant is. Extract from observation schedule – Simone posing a question to her Grade 3 class, May 2013: 'Is it a wild animal or is it a tame animal?' A learner said it is a wild animal. She then asked: 'What are the types of animals that we can keep at home?' Some learners mentioned dogs and cats. Extract from observation schedule – Simone posing a question to her Grade 3 class, May 2013: 'What type of animals are those?' When there was no response she asked, 'Are they wild or are they tame?' The learners said they are tame animals.

Simone then drew a table on the chalkboard showing wild and tame animals. One learner said a chicken could be kept as a pet. Simone said that the chicken is not kept as a pet but for eating purposes. Simone drew the learners' attention to the list of wild animals and asked the learners to name an animal from the list that was a predator. Extract from observation schedule – Simone posing a question to her Grade 3 class, May 2013: 'What do predators do?' She answered that they eat other animals and proceeded to ask the learners to name one animal from the list of wild animals that eats another animal as a meal. A learner mentioned the lion. Extract from observation schedule – Simone posing a question to her Grade 3 class, May 2013: 'we get tame animals, domesticated animals and predators and we get carnivores and herbivores'.

A second lesson on animals was taught during the observation period. Simone wrote the words: herbivore, fierce, carnivore, extinct, alive, shadows, ancient, sharp, strong, huge, fast and slow on a flipchart. Simone explained the meaning of each word and proceeded to read a story about disappearing wildlife and used the Jackass/African penguin as example. Extract from observation schedule – Simone posing a question to her Grade 3 class, May 2013: 'Why the penguins' bellies are white and the sides black?' She then instructed them to find out why this is so. She continued by telling the learners that the penguins are an endangered species and proceeded to ask the group questions based on the story.

A further aspect discussed during the observation week was animal homes. There were two sections to the worksheet. For the first section, learners had to draw lines to join the home to the animal. For the second section, they had to complete sentences. The first section showed bees living in a honeycomb and in the second section bees' homes were called hives. Simone then wrote a few sentences on the chalkboard where learners had to choose the right word and fill in the blanks. The exercise was on defining herbivores and carnivores.

The next lesson started with Simone presenting a big poster from Young Wildlife and Folklore from Africa and read from the poster about the diversity of African mammals and the different reproductive styles. Simone had difficulty with the pronunciation and explanation of the terms, for example 'parental care.' This concept could have been explained in a much simpler way than that which was read from the poster. While reading Simone seemed to be making herself understand first before trying to explain to the learners. As Simone read, she paused to explain to learners. It was clear that the poster on animals was not age appropriate for a Grade 3 class as Simone also experienced difficulty with pronunciation. Simone continued:

> 'There are wild animals. We need wild animals too. There is a food chain. We all are part of the food chain and after break we are going to do the food chain.' (Extract from observation schedule: Simone teaching her Grade 3 class, May 2013)

Simone then wrote an exercise on matching animal sounds on the chalkboard. Learners had to match the animals to the sounds they make, bleats, neigh, bellows, brays, mew, trumpet and barks. Learners called out different answers. However, Simone did not respond to any of their answers. Although Simone asked many questions during the lessons, she did not always give learners enough time to answer; often answering the questions herself or she moved on without providing the answers.

Analysis of the Grade 3 learners' books revealed that there was no evidence of scientific investigations or hands-on science in the teaching of natural science and no scientific investigation was noted during the observation. During the interview, Simone was asked whether she ever allowed learners to conduct investigations. Her response was:

> 'Basically we don't … because of our large class sizes when we want to do science we come outside. I mean like capacity and things like that, water, and things like that … we have to go outside, put them in the corridor or put them by the taps. We take buckets.' (Extract from observation schedule: Simone teaching her Grade 3 class, May 2013)

Simone's science content knowledge was better than that of the other teachers' although her questioning techniques were poor, often confusing the learners. Although no practical, hands-on science activities were observed, learners were more constructively engaged than learners in the other Grades; they drew bar graphs and compared different animals.

**TABLE 4:** Simone's level with regard to her profile of implementation of three sub-constructs.

| Level | Classroom interaction | Hands-on science and investigations | Knowledge and understanding of science content and concepts |
|---|---|---|---|
| 1 | - | No evidence of hands-on science to help develop concepts. Learners were not practically involved in the lesson | - |
| 2 | Some participation as learners answered questions and engaged in activities | - | Some correct science concepts were taught |

Table 4 shows the levels for the three sub-constructs used to determine Simone's profile of implementation with regard to natural science teaching. She was at level 1 for hands-on science and scientific investigations as there was no evidence of this. While the structure and sequencing of topics were somewhat disorganised, Simone managed to teach a few science concepts and was therefore placed at level 2. Learners participated by providing answers and engaging in given tasks placing her at level 2 for this construct as well (Table 4)

## Discussion

All three teachers who taught science lessons experienced challenges teaching science content and concepts. Their limited knowledge resulted in them giving learners incorrect information and not being able to correct learners' misconceptions. For example, Fiona presented learners with incorrect information that fish come out of the water to breathe and demonstrated limited knowledge of bilharzia. Fiona's lack of science content knowledge led her to focus on health issues. Carly's science lessons were also characterised by inaccuracies and misconceptions. Her lack of scientific knowledge was demonstrated by her use of an inappropriate chart on insects.

Of the three teachers, Simone made the most effort to teach science. She taught a number of science lessons and demonstrated some knowledge of science concepts, although her lessons were poorly structured and at times confusing to the learners. Although Simone attempted to teach science concepts, her knowledge in some instances was either scanty or incorrect.

The lack of ability to teach accurate science content and explain science concepts accurately paints a poor picture of teachers' profiles of implementation. Evidence of their poor science content knowledge supports studies conducted elsewhere (Appleton 2008; Waters-Adams 2006). All three teachers demonstrated how a lack of subject knowledge impacts on the lesson structure as all the lessons observed were unstructured and showed very little evidence of coherence. All three teachers tended to jump from one topic to the next. The lack of content knowledge meant that the teachers had no pedagogic content knowledge either as they did not know how to structure their lessons or what type of questions to ask to encourage learners to think. Questions were often random, and it was difficult to follow what the teacher's intentions were. Teachers often answered their own questions. The lack of hands-on practical activities or structured investigations can also be attributed to a lack of content knowledge. Karen and Fiona, for example, lacked an understanding of what is meant by hands-on science given their explanation of hands-on science activities. Their lack of confidence prevents them from attempting to implement hands-on activities. While the topics taught by Fiona and Carley were suitable for some kind of hands-on activity, such as direct observation or collection, Simone's lesson lent itself to a basic inquiry-based approach but this was not observed.

Observation of the four teachers over a period of time, however, showed that they possessed the ability to interact with learners, use resources and engage learners in activities. This points to a degree of pedagogic knowledge and raises the question of how these skills could be used to improve their science teaching? While research indicates that there are very few science components in initial teacher education programmes (Bartholomew, Anderson & Moeed 2012) which explains their poor science knowledge, the topics the teachers selected to teach were fairly simple and taught year after year. It would appear that an experienced teacher could prepare herself better with regard to scientific knowledge. This was evident in Simone's case: slightly better content knowledge enabled her to ask more questions and engage learners better. Teachers with good pedagogic knowledge could develop pedagogic content knowledge if their science knowledge improved. Improved pedagogic content knowledge would enable teachers to include hands-on science activities as well as science investigations in their lessons.

## Conclusion

Although the teachers in this study receive little support from curriculum documents as no clear guidelines exist with regard to what and how science should be taught and little emphasis is placed on science learning, some responsibility should rest with teachers to take science teaching more seriously. Unfortunately, science education for young children is not foregrounded in the South African curriculum and consequently teachers appear not to see the importance either. If we wish to improve the quality of science teaching in the foundation phase the time has come to foreground science as a learning area in the foundation phase curriculum and to make science education a compulsory component of teacher education programmes.

## Acknowledgements

The research is based on the thesis of one of the authors at the University of KwaZulu-Natal, entitled 'Foundation phase teachers' interpretation and implementation of the natural science curriculum in the life skills learning programme: A case study' by Saritha Beni.

### Competing interests

The authors have declared that no competing interests exist.

### Authors' contributions

All authors conceptualised the research, developed the data collection instruments, contributed to the literature review and wrote the manuscript. S.B. collected and analysed the data in consultation with A.A.J. and M.S. A.A.J. and M.S. developed the structure for reporting the research. All three authors contributed to writing the manuscript.

### Funding information

No funding or other support was obtained for this.

## Data availability statement

Data sharing is not applicable to this article as no new data were created or analysed in this study.

## Disclaimer

The views expressed in the article are those of the authors and not an official position of the institution or funder.

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Appendices starts on the next page →

# Appendix 1: Observation schedules for classroom observations

| Level | Classroom interaction | Hands-on science or science investigation | Science knowledge |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |

*Source*: Rogan, J.M. & Grayson, D.J., 2003, 'Towards a theory of curriculum implementation with particular reference to science education in developing countries', *International Journal of Science Education* 25(10), 1183.

**FIGURE 1-A1:** Profile of implementation.

# Appendix 2: Criteria for each level of the profile of implementation (informed by Rogan and Grayson's model, 2003)

**TABLE 1-A2:** Composite levels for a teacher's profile of implementation with regard to natural science teaching.

| Level | Classroom interaction | Hands-on science/scientific investigations | Knowledge of science content and concepts |
|---|---|---|---|
| 1 | Structure of lessons was disorganised, not well-sequenced<br>Teacher used no resources<br>Teacher hardly engaged learners with questions and often answered the questions herself<br>Teacher did not engage learners in meaningful learning activities which results in learners losing concentration and being disruptive | No evidence of hands-on science to help develop concepts<br>Learners were not practically involved in the lesson<br>No evidence of scientific investigations | Teacher had minimal science content knowledge<br>Teacher was not confident to teach natural science as there was no science taught |
| 2 | Teacher presented content which showed some organisation and sequence<br>Teacher used resources<br>Teacher engaged learners with questions; however, the teacher did not always give learners enough time to respond to questions<br>Teacher engaged learners in minimal meaningful learning activities which resulted in maintaining learners concentration most of the time | Minimum evidence of hands-on science to help develop concepts<br>Minimum involvement of learners in the lesson<br>Minimal evidence of scientific investigations which was teacher controlled | Teacher had limited science content knowledge<br>Teacher was not very confident to teach some aspects of natural science |
| 3 | Teacher presented content in a well-organised and well-sequenced manner<br>Teacher used resources effectively<br>Teacher engaged learners with questions and provided adequate time for learners to respond<br>Teacher engage learners in meaningful learning activities; however, they did not promote doing practical scientific activities | Clear evidence of hands-on science to help develop concepts<br>Learners participated in closed practical work<br>Scientific investigations were initiated by teacher with learners working in groups to carry out the investigations | Teacher had adequate science content knowledge<br>Teacher was confident to teach most content areas of natural science |
| 4 | Teacher presented content in a well-organised and well-sequenced manner that promoted practical scientific investigations<br>Teacher used textbooks/workbooks effectively along with other resources<br>Teacher engaged learners with questions that encourage in-depth thinking<br>Teacher engaged learners in meaningful learning activities that promoted doing practical scientific activities | Teacher designed hands-on science in such a way that encouraged learner discovery of information<br>Learners performed 'guided discovery' type practical work in small groups engaging in hands-on activities<br>Scientific investigations was initiated by the learners with learners working in groups or individually to carry out the investigations | Teacher had a professional qualification appropriate for the foundation phase which included a strong natural science component<br>Teacher was very confident to teach natural science |

*Source*: Adapted from Rogan, J.M. & Grayson, D.J., 2003, 'Towards a theory of curriculum implementation with particular reference to science education in developing countries', *International Journal of Science Education* 25(10), 1171–1204.

# Appendix 3: Document analysis

| Date (learners' written work) | Evidence of science lessons: Comment on the following aspects: | | |
|---|---|---|---|
| | Hands-on science | Scientific investigations | Science content |
| | | | |
| | | | |

**FIGURE 1-A3:** Learners workbooks.

# Appendix 4: Interview schedule

**BOX 1-A4:** Example of semi-structured questions.

The semi-structured interview was based on the data obtained from the classroom observations. These are some types of questions that were asked:

1. You mentioned that you use demonstrations often as an instructional method in teaching science.
   1.1 Can you explain, using an example from your teaching how you accomplished this?
   1.2 How do the learners respond when you carry out a demonstration during a science lesson?
2. You mentioned that you attended a professional development workshop on teaching science.
   2.1 Describe the workshop you attended? What was the focus?
   2.2 Explain what you learnt at the workshop?
   2.3 Did you find it helpful/not helpful in your science teaching?
   2.4 Why was it helpful/not helpful?
3. From the classroom observations, I observed you did.....during your science lesson.
   3.1 Why did you do that?
   3.2 Where did you get the idea from?
4. Any questions based on what was observed during the classroom observations.