International Journal of Learning, Teaching and Educational Research
Vol. 20, No. 5, pp. 18-37, May 2021
https://doi.org/10.26803/ijlter.20.5.2

The Development and Use of Improvised Science-Teaching Models: A Case of Natural Science Pre-Service Teachers

Wiets Botes
School of Education, Department of Natural Science and Mathematics Teaching,
Sol Plaatje University, Kimberley, South Africa
https://orcid.org/0000-0002-3024-8969

Abstract. The study aimed to describe how a team of final-year pre-service teachers followed the process of improvisation to develop and utilise improvised science-teaching models during a teaching practicum experience. Guided by a conceptual understanding of the process of improvisation, this purposeful qualitative case study sought to respond to a series of research questions. These research questions are: "What are the issues that necessitate the need to develop science-teaching models for a teaching practicum experience?", "How could the process of improvisation enable Natural Science pre-service teachers to develop improvised science-teaching models for a teaching practicum experience?" and "To what extent do the Natural Science pre-service teachers utilise the improvised science-teaching models in their teaching practicum?" Data collection methods such as spontaneous free-response e-mail communications, a focus-group discussion, and the use of photo-voice methodology yielded rich empirical data. The findings revealed how the Natural Science pre-service teachers ultimately engaged with the improvisation principles to develop improvised science-teaching models from low-cost and recycled materials. The paper further describes how the improvised science-teaching models were introduced in the pre-service teachers' Natural Science lesson delivery as part of a model-based teaching approach. Findings from the study suggest that initial teacher education programs render environmental and contextual consciousness in shaping pre-service teachers for the diverse schooling contexts. The study further suggests that initial teacher education programs be intentional towards structuring module course material to make the skill of improvisation accessible to pre-service teachers as part of their teacher development.

Keywords: model-based science-teaching; improvisation; Natural Science education; pre-service teacher development

1. Introduction and background to study

Natural Science is informed by knowledge areas that deal with life and living, matter and materials, energy and change, and earth and beyond. These topics stem from various disciplines such as Biology, Chemistry, Physics, and Earth and Space sciences (DBE, 2011). With these topics in mind, a key attribute towards a quality Natural Science teaching experience is the ability of a Natural Science educator to convey what Shulman (1987) decades ago referred to as sound pedagogical content knowledge for scientific inquiry. The latter is regarded as a specific instantiation of pedagogical content knowledge fit to the teaching of Natural Science as a middle-school subject (Peel et al., 2019). This particular form of pedagogical content knowledge includes a combination of science-specific content knowledge, educational knowledge, and teaching methodology that science educators should be equipped with to facilitate learners' comprehension of scientific phenomena (DHET, 2015; Pareek, 2019).

With this attribute in mind, the expectation is that Natural Science pre-service teachers in development master the skill to teach Natural Science in an innovative, inclusive and practical manner (Stears & James, 2011). In the context of initial teacher education, one such way to develop this skill is through enabling pre-service teachers to utilise a model-based teaching approach as part of their lesson design and delivery (Peel et al., 2019). Over the past couple of decades, using a model-based teaching approach has been increasingly recognised among the science education community (Black, 1962; Perkins, 1986; Gobert & Buckley, 2000; Ingham & Gilbert, 1991; Peel et al., 2019). Some claim that the idea of model-based learning takes centre stage in K-12 science education (Bryce et al., 2016).

According to Harlow (2010) and Seel (2017), a model-based teaching approach is understood as a teaching approach that brings together a teacher's subject content knowledge and teaching methodology. It compliments it with the aid of explanatory models to assist learners in visualising an idea, system or process. In other words, by following a model-based teaching approach, learners would be able to link an abstract concept and a real-life situation. One such example includes utilising a DNA double helix model to explain the characteristics of the DNA structure. Another example could be a model that displays the atomic structure of particles, hence representing the atom. In other words, a model serves as a simplified representation of a system, which details critical aspects of the system (Peel et al., 2019; Ingham & Gilbert, 1991). Thus, the understanding is that a model-based teaching approach promotes visualisation in learners (Damelin et al., 2017). The invisible (for instance, the atomic structure of the DNA double helix structure) becomes visible through physical representation.

For this reason, the expectation is that pre-service teachers follow a model-based teaching approach towards their teaching practicum since it would allow for a more informed explanation of abstract biological, physical, and chemical phenomena (Taber, 2017). This aligns well with the view of Pareek (2019) when it is suggested that the utilisation of a model-based teaching approach allows for an enjoyable "hands-on" and "minds-on" learning experience. Simply put, using model-based teaching lends credence and reality to the abstract concepts and

terminology of science education (Okori & Jerry, 2017) and translates into a learning experience that fosters learners' ability to engage in scientific reasoning (Dare et al., 2019). Other researchers remind us that a model-based teaching approach in the science classroom stimulates learners' general interest in the subject of Natural Science (Tsybulsky, Dodick & Camhi, 2018).

Unfortunately, given the benefits towards the use of a model-based teaching approach in the context of science education, several factors seem to restrict middle-school Natural Science educators from using models in their lesson design and delivery (Akuma & Callaghan, 2016; Harlow, 2010; Okori & Jerry, 2017; Philip, 2019; Singh & Singh, 2012). In a South African teaching context, it has been reported that although the South African Department of Basic Education galvanised efforts and resources towards improving the quality of Natural Science education (Munje & Jita, 2020), some South African scholars reported on a multitude of issues that hampers science educators' ability to implement a model-based teaching approach in their teaching (Mtsi & Maphosa, 2016; Mupira & Ramnarain, 2018; Mzuza & Van der Westhuizen, 2019; Ramnarain, 2020).

A study by Mzuza and Van der Westhuizen (2019) found that in the Northern Cape province, which is the largest and most sparsely populated province of South Africa, many schools in rural and disadvantaged areas were plagued with Science classrooms. These classrooms were not well-equipped with the deemed Natural Science teaching models. This echoes the view of local scholars such as Du Plessis and Mestry (2019), who claim that ill-resourced Science classrooms characterise a significant number of South African schools in rural and disadvantaged areas. In addition, studies by Mabasa and Singh (2020) and Mupira and Ramnarain (2018) shed light on the outdated science-teaching models that are not aligned to the current national school curriculum, also referred to as the Curriculum and Policy Statement document.

This particular issue, which is associated with the lack of science-teaching models in selected middle-schools, harms the ability of pre-service teachers to demonstrate their competence in pursuing a model-based teaching approach during practicum teaching opportunities. Given the reality of ill-resourced Science classrooms in selected schools in the Northern Cape province, national scholars (Fleischmann & Van der Westhuizen, 2017; Mupira & Ramnarain, 2018; Nkambule & Mukeredzi, 2017) and international scholars (Aadland, Espeland & Arnesen, 2017) call on teacher development programmes to be intentional in developing pre-service teachers' capability to develop and utilise improvised teaching models as a means to complement their model-based teaching approach during teaching practicum opportunities.

Given the preceding argument, which described various issues associated with the unavailability of science-teaching models, this study sought to document how the process of improvisation enabled a team of final-year Natural Science pre-service teachers to develop and utilise improvised science-teaching models for a teaching practicum experience. Guided by a conceptual understanding of the process of improvisation, this purposeful qualitative case study responds to a

series of research questions. These research questions are: "What are the issues that necessitate the need to develop science-teaching models for a teaching practicum experience?", "How could the process of improvisation enable Natural Science pre-service teachers to develop improvised science-teaching models for a teaching practicum experience?" and "To what extend do the Natural Science pre-service teachers utilise the improvised science-teaching models in their teaching practicum?"

A response to these research questions will clarify the pre-service teachers' ability to strategise ways to develop teaching models, thus displaying the skill of improvisation, which scholars such as Aadland, Espeland and Arnesen (2017) and Ramnarain (2020) regard as a professional teaching skill. Consequently, their development of the skill to improvise the design of science-teaching models would positively impact their quality of teaching and allow learners to enjoy the benefits of a more engaging and joyful science learning experience.

2. Problem Statement

This study was conducted in a School of Education at an institution of higher education in South Africa. The study involved seven final-year pre-service teachers specialising in teaching the subject Natural Science in the intermediate phase, also commonly referred to as "middle-school" teaching. As part of their teacher development, the pre-service teachers were placed in schools in the city where the university is located for four weeks to perform practicum teaching.

During this time, the pre-service teachers expected to prepare and present lessons that would allow a meaningful science teaching experience. This included the pre-service teachers using a model-based science teaching approach that would elicit a "hands-on" and "minds-on" learning experience, thus enabling learners to make meaning of abstract science concepts. However, upon the pre-service teachers' arrival at the schools where they had been placed to perform their practicum teaching, the pre-service teachers realised that the science classrooms were ill-resourced with little to no relevant science teaching models to use in their science teaching.

Their frustrations with a lack of science-teaching models at their disposal were communicated with their module lecturer, who also served as the Researcher and author of this article. The realisation of the lack of science teaching materials available to pre-service teachers during a practicum teaching experience prompted my interest in conducting this study. This study sought to describe how a team of final-year pre-service teachers followed the process of improvisation to develop and use improvised science-teaching models during a teaching practicum experience.

3. Conceptualising the process of improvisation in the context of initial teacher education

The common understanding is that social challenges require systematic solutions grounded in contextual and personalised expertise (Harlow, 2010; Ozuah, 2019). In other words, through acknowledging the contextual expertise that individuals

have to offer, the process of improvisation seeks to create a solution that speaks to them individually identified needs of others. To contextualise, this study responds to a team of final-year Natural Science pre-service teachers' need to develop science-teaching models that would complement their Natural Science teaching during teaching practicum opportunities.

Traditionally, the process of improvisation was recognised as a complex problem-solving process in performing arts, drama, and music education (Barbara & Sam, 1957; Borko & Livingston, 1989; De Bruin, 2019; Erickson, 1982; Sawyer, 2004; Yinger, 1987). However, more recently, the field of teacher education also adopted the approach, with researchers describing how the experimental and open nature of improvisation is considered helpful in dealing with teaching and learning-related matters (Hickey, 2015; Sawyer, 2011). To be specific, studies by Aadland, Espeland and Arnesen (2017) and Okori and Jerry (2017) described how the process of improvisation assisted educators to structure teaching models from low-cost and recyclable materials.

Improvised teaching and learning models serve as low-cost goods developed from materials such as plastics, cardboard and tin cans, to name but a few (Akuma & Callaghan, 2016; Holdhus et al., 2016). Yeboah, Abonyi and Luguterah (2019) share a similar understanding of improvised teaching and learning models. They refer to them as teaching models created from local and readily available resources due to the unavailability of original teaching models. For educational purposes, teaching models are considered highly effective towards promoting a quality educational experience (Holdhus et al., 2016).

At its core, the process of improvisation is informed by three overlapping principles. These include the principles of inspiration, ideation and implementation. These principles ultimately manifest in the process of improvisation (Eze, 2018; Ponzio et al., 2018). As a starting point, the principle of inspiration serves as a space that allows for identifying and clarifying individually identified needs and the drive towards the search for a solution (Philip, 2019). Thus, the understanding is that the principle of inspiration allows one to understand the extent to which the need impacts the professional capability of others. Information related to the principle of inspiration can be obtained through focus-group discussions, interviews, and surveying. However, obtaining an in-depth understanding of the need of others requires one to form part of the reality of others (Philip, 2019). This approach allows for a first-hand and personalised "observed" experience (Wrigley & Stalker, 2017). Simply put, the principle of inspiration is considered a product that derives from the individual needs of others.

The process of improvisation further draws on the principle of "ideation". As the second core principle, ideation enables individuals to distil ideas into insights that could serve as potential strategies to the needs identified (Aadland, Espeland & Arnesen, 2017). This free flow of ideas and information sharing can also be referred to as divergent thinking. Everyday activities used to capture the principle of ideation includes focus-group discussions, brainstorming sessions and visual

representations of ideas. In this study, the principle of ideation was put into motion when the team of final-year pre-service teachers strategised ways to develop science-teaching models from low-cost or recycled goods. This approach was followed to respond to the lack of teaching models available to them during their teaching practicum duties.

The third and final principle that informs the process of improvisation is prototyping and implementation (Eze, 2018). The principle enables an individual to implement the strategy in an authentic "real-world" context. Prototyping is seen as a process where the strategy that stems from the principle of ideation is tested and re-tested to uncover unforeseen challenges that could negatively impact the strategy's effectiveness (Wrigley & Stalker, 2017). Once the strategy has been re-defined, and the necessary adjustments were made to improve the strategy, implementation can occur. The impact and effectiveness of the strategy can be verified through various means such as focus-group discussions, interviews, observations, reflective entries and surveying.

4. Research approach and methodology

The study followed a purposeful qualitative case study approach. The case included seven final-year Natural Science pre-service teachers and their ability to follow the process of improvisation to develop science-teaching models. Permission was granted by the Postgraduate Research Ethics Committee of the University of the Free State (Ethical clearance number - UFS-HSD2018/0073). As the principal Researcher, one was tasked to ensure that all relevant role-players involved in the study were consulted in advance (Creswell & Creswell, 2017). Therefore, the Natural Science pre-service teachers were approached to give consent to take part in the study. In addition, the team was also assured confidentiality throughout the research process. It was also made clear that they were allowed to withdraw from the study at any time. A consent form was signed by each of the Natural Science pre-service teachers, which was archived for record-keeping purposes.

The research site was situated in a School of Education at a South African University. The School of Education offers a Bachelor of Education degree with multiple areas of specialisation in the intermediate phase (grade 4 – 6 teaching), senior phase (grade 7 – 9 teaching) and further education and training phase (grade 10 – 12 teaching). For this particular study, the research participants comprised seven final-year pre-service teachers specialising in the teaching of Natural Science in the intermediate phase, also commonly referred to as "middle-school" teaching.

The study aimed to describe how a team of final-year pre-service teachers followed the process of improvisation to develop and utilise improvised science-teaching models during a teaching practicum experience. In order to achieve this aim, the study responded to three pertinent research questions. The use of spontaneous free-response e-mail communications penned by the Natural Science pre-service teachers shed light on the first research question of the study. The question posed was to describe the issues that necessitate developing science-

teaching models for a teaching practicum experience. A response to this research question would allow the team to follow a creative approach towards strategising ways to circumvent the issue associated with science-teaching models. The rich qualitative data obtained from the free-response e-mail communications were captured, thematically analysed and transcribed.

Additionally, establishing a focus-group discussion between the module lecturer and the team of final-year pre-service teachers was vital in responding to the study's second research question. The second research question sought to investigate how the process of improvisation could enable Natural Science pre-service teachers to develop improvised science-teaching models for a teaching practicum experience. The team's responses that stemmed from the focus-group discussion were audio-recorded, analysed and transcribed. Besides the focus-group discussion, the use of photo-voice methodology was also utilised to give voice and expression to the improvised science models that the team created. The use of photo-voice methodology further allowed for an in-depth exploration and interpretation of the pre-service teachers' models developed from low-cost goods and recycled materials.

In order to respond to the aspects of credibility, reliability and validity (Creswell & Creswell, 2017), the data derived from the spontaneous e-mail communication, focus-group discussion and photo-voice methodology were shared among the pre-service teachers. This study determined whether the transcribed text and captured photographs were a true reflection of their accounts.

5. Findings

The three research questions of the study yielded rich empirical data. Table 1 provides a synopsis of the themes and categories that emerged from the study as a point of departure. These themes and categories are also aligned with the research questions of the study. Thereafter, a more in-depth interpretation and descriptive explanation of the themes will follow.

Table 1. Synopsis of the themes and categories.

Research questions	Data collection technique	Themes	Categories
What are the issues that necessitate the need to develop science-teaching models for a teaching practicum experience?	E-mail communication	**Confronting the challenge** associated with the unavailability of science-teaching models	- Lack of science-teaching models during teaching practicums; - Lack of model-based teaching; - Pre-service teacher frustrations with practical teaching.
How could the process of improvisation enable Natural Science pre-service teachers to	Focus-group discussion	**Realising the need** to develop improvised science-teaching models	- Pre-service teacher determination; - Envisioning a meaningful Natural Science (NS)

develop improvised science-teaching models for a teaching practicum experience?			teaching and learning experience.
	Photo-voice methodology	**The development** of improvised science-teaching models	- Science models designed from low-cost materials; - Science models designed from recycled goods; - Creativity and innovation.
To what extent do the Natural Science pre-service teachers utilise the improvised science-teaching models in their teaching practicum?	Photo-voice methodology	**The implementation** of improvised science-teaching models	- Model-based teaching in action; - Inquiry-based learning.

Responding to research question 1:
The first research question sought to describe the issues that necessitate developing science-teaching models for a teaching practicum experience. With this research question in mind, the Natural Science pre-service teachers' responses pointed to a predominant theme, namely "the unavailability of science-teaching models". Categories such as "lack of science-teaching models during teaching practicums", "lack of a model-based teaching approach", and "pre-service teacher frustrations with practical teaching" informed the challenge associated with the unavailability of science-teaching models. Theme 1 is described next.

Theme 1: <u>Confronting the challenge</u> associated with the unavailability of science-teaching models (Responding to the principle of inspiration)
The first principle that informs the process of improvisation is referred to as inspiration. The principle of inspiration enables one to clarify individually identified needs and is considered a driver towards searching for a solution. In other words, it allows individuals to be creative towards strategising ways to circumvent existing issues that might exist. This step was also crucial to responding to the first research question of the study. In this study, the principle of inspiration surfaced when the pre-service teachers voiced their concerns regarding the unavailability of science-teaching models during teaching practicum opportunities. This can be confirmed in spontaneous e-mail communication penned by a pre-service teacher and communicated to the module lecturer, who also served as the study researcher.

> *"Good day, Sir*
> *Sir, the crits [lesson observation procedures] are next week. I'm already worried because the class does not have any models for us to use. I mean I plan my NS [Natural Science] lesson the day before just to find out that no models are available. We are then forced to stick to the textbook because there is nothing that we can use to show them [learners] how the plant cell really looks. Aren't there any way to deal with this?"*
>
> *Participant 7; spontaneous e-mail response*

The subjective response provided by the pre-service teacher delivers multiple meanings. In short, the response sheds light on the lack of science-teaching models available to the pre-service teachers' during teaching practice duties. This can be confirmed by the pre-service teacher when it was mentioned that "I mean I plan my NS [Natural Science] lesson the day before just to find out that no models are available". Furthermore, given the pre-service teacher's intention to utilise a model-based teaching approach, the unavailability of science-teaching models negatively affects their ability to practice a model-based teaching approach, as the pre-service teacher declared that "there is nothing that we can use to show them [learners] how the plant cell really looks." The pre-service teacher's cry for help in terms of circumventing the issue was also made clear when the pre-service teacher posed the question "Aren't there any way to deal with this?". Therefore, the assumption is that "something has to be done" to address the challenge associated with a lack of science-teaching models.
The severity of the challenge was further reiterated in another e-mail response that was communicated to the module lecturer.

"Hi Sir,
I was at your office but you were not in. Can I come see you tomorrow after school? I'm a bit lost and need help with teaching aids [models]. I will be on campus around 3 [15:00] to hopefully fetch some equipment for my lesson this coming week."
Participant 5, spontaneous e-mail response

The e-mail response provided by the pre-service teachers again reiterates the complications surrounding the lack of teaching models available to the pre-service teachers during teaching practicum duties. In this particular response provided, one picks up a sense of urgency and desperation in the pre-service teachers' voice. This can be confirmed by the phrases "I was at your office, but you were not in", "Can I come see you" and "I'm a bit lost and need help". In addition, the phrase "fetch some equipment for my lesson this coming week" points to the pre-service teacher's intention to use teaching models to aid a model-based teaching approach for a particular Natural Science lesson.

Responding to research question 2:
The second research question sought to describe how the process of improvisation can enable the Natural Science pre-service teachers to develop improvised science-teaching models for a teaching practicum experience. With this research question in mind, a focus group discussion with the team of pre-service teachers allowed for the formulation of the theme "realising the need to develop improvised science-teaching models". Categories that supported this theme included "pre-service teacher determination" and "envisioning a meaningful NS teaching and learning experience". Theme 2 is described next.

Theme 2: <u>Realising the need</u> to develop improvised science-teaching models (Responding to the principle of inspiration cont.)
To this end, the issue associated with the lack of science-teaching models was clarified based upon the spontaneous e-mail communications communicated to the module lecturer, who also served as the Researcher. Given this clarification, the module lecturer decided to establish a focus-group discussion to circumvent the issue identified, therefore responding to the study's second research question.

The focus group discussion took place during the initial stages of the pre-service teachers' school visitation practical teaching process. During the focus group discussion with the team of Natural Science pre-service teachers, the Researcher asked, "What can be done to overcome the issue associated with the lack of science-teaching models?" With this question posed, one of the pre-service teachers had the following to say:

> *"Guys it's a fact, most of us struggled with no equipment [science-teaching models]. Well, maybe we can try and make some of these things [science-teaching models] ourselves, you know. We can just look around for stuff to use and just do. It can just be basic or whatever, but at least the kids will see [observe]. That will also help us to not only use textbook teaching the whole time."*
>
> *Participant 3, free-attitude verbal response*

This response provided declares a pre-service teacher's urge to follow the process of improvisation to develop their science-teaching models. This statement can be supported by the phrases "look around for stuff to use and just do it". In addition, the phrase "It can just be basic, or whatever" points to the pre-service teacher's intention to develop science-teaching models from readily available materials, which in this case are recycled and low-cost goods. The phrases "will also help us to not only use textbook teaching the whole time" and "at least the kids will see" are indicative of a typical model-based teaching approach which would be helpful towards deepening and promoting the learners' understanding of complex science topics in the Natural Science classroom. Both these phrases suggest that the pre-service teacher wishes to establish a teaching environment that would explain science-related topics more simplistically, thus promoting a quality science learning experience.

The use of photo-voice methodology further shed light on how the process of improvisation enabled the Natural Science pre-service teachers to develop improvised science-teaching models for a teaching practicum experience. An analysis of a series of photographs taken allowed for the formulation of the theme titled "physical development of improvised science-teaching models". Categories that supported this theme included "science models designed from low-cost materials", "science models designed from recycled goods", and "creativity and innovation". Theme 3 is described next.

Theme 3: <u>The development</u> of improvised science-teaching models (Responding to the principle of ideation)

The second principle that informs the process of improvisation is ideation. The principle of ideation enables individuals to distil their ideas into insights that could serve as potential strategies to respond to the challenges identified. Given the challenge associated with the lack of teaching models, the team of pre-service teachers set out to put their creative ideas into motion, thus staying true to the true meaning of ideation.

What follows next is a showcase of some of the improvised science-teaching models that the pre-service teachers developed from low-cost and recycled goods. The models were photographed, and the nature of the models is briefly described in figures 1 to 4 below.

"The plant cell"	

Model description

The model shown here provides a simple visual representation of the plant cell. The model shows the different organelles that make up the plant cell. One further finds that the model has an aesthetic appeal that would allow the Natural Science pre-service teacher to communicate the different organelles of the plant cell to the learners. A closer look at the model of the plant cell confirms its design made up of low-cost and recycled materials such as a shoebox (representing the cell wall), condom (representing the vacuole of a cell with a watery substance) and soap bars (representing the mitochondria).

Figure 1. The plant cell as a science-teaching model.

"The DNA structure"	

Model description

The model shown here provides a basic yet visually appealing representation of the DNA double helix structure. Although the different parts of the DNA double helix structure are not clearly labelled, the learners could still distinguish the different nucleotide structures (adenine pairing with thymine and cytosine pairing with guanine) through colour matching (blue pairing with blue & pink pairing with pink). For instance, the Natural Science pre-service teacher will demonstrate that the pink marshmallow sweets represent a nucleotide pair comprising thymine and adenine. On the other hand, the blue marshmallow sweets represent the other nucleotide pair comprising guanine and cytosine. The Natural Science pre-service teacher will also show the learners that the DNA structure is curved and spiral-shaped as the model provides a three-dimensional representation of the DNA double helix structure. One also finds that the model was designed from low-cost and recycled materials such as carton and marshmallow sweets.

Figure 2. The DNA double helix as a science-teaching model.

"The water cycle"	

Model description

The model shown here provides a visual representation of the water cycle. The different stages involved in the water cycle are indicated with relevant labelling and drawings. What makes the model unique is the fact that the natural pre-service teacher could capture the water cycle as part of a system of events. To be specific, a closer look at the model reveals the four main stages (evaporation, condensation, precipitation and collection) that inform the water cycle. Again the model was designed to form low-cost and recycled materials such as the shoebox (portraying the earth and atmosphere respectively), leaves (representing trees), gravel and sand (representing the crust of the earth).

Figure 3. The water cycle as a science-teaching model.

"Lung model"	

Model description

The model shown here are representative of how the lung functions in terms of the processes of inhalation and exhalation in breathing. In this instance, the pre-service teacher created a lung model from recycled materials such as a plastic bottle, two straws, an elastic band and a balloon.

Figure 4. The lung model as a science-teaching model.

Responding to research question 3:

The third research question sought to describe the extent to which the Natural Science pre-service teachers utilise the improvised science-teaching models in

their teaching practicum. Again the use of photo-voice methodology allowed for the formulation of the theme titled "the implementation of improvised science-teaching models". Categories such as "model-based teaching in action" and "evidence of inquiry-based learning" informed the theme. Theme 4 is described next.

Theme 4: The <u>implementation</u> of improvised science-teaching models (Responding to the principle of implementation)

The third and final principle that informs the process of improvisation is implementation. For this study, the principle of implementation was seen as a process whereby the developed science-teaching models were put to the test in an authentic teaching space, thus responding to the third research question of the study. This was done to determine whether the science-teaching models had any significant impact on the quality of their model-based teaching.

In order to provide an account of this principle in action, the Researcher was able to analyse, interpret, and describe how some pre-service teachers went about using the improvised teaching models as part of their model-based teaching approach during teaching practicum opportunities. What follows next is a synopsis of two teaching scenarios that provides evidence of a model-based teaching approach through the use of the photo-voice methodology.

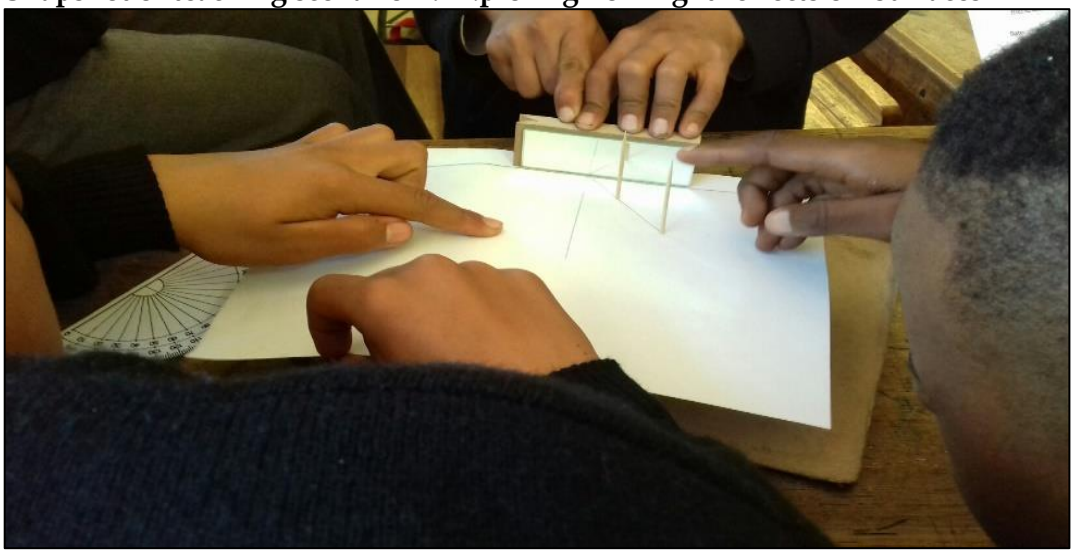
Snapshot of teaching scenario A: Investigating how the respiratory system functions through the use of a lung model

Observations made by the Researcher:

A closer look at this teaching scenario reveals how the Natural Science pre-service teacher could use improvised science-teaching models in an authentic teaching context. In this teaching scenario, the Natural Science pre-service teacher allowed the learners to build lung models from recycled materials (plastic bag, plastic bottle, straws, elastic band) to understand better how the respiratory system functions. After the learners built their lung models from materials that the Natural Science pre-service teacher provided, the learners showed how air is pulled in and out of the lungs. The learners could demonstrate how the diaphragm, as a thin skeletal muscle, contract and flattens when a person inhales,

which results in air being pulled into the lungs. They demonstrated that when a person exhales, the diaphragm relaxes, which forces air out of the lungs. The assumption is that the learners were challenged to observe how the diaphragm contracts and flattens by using the improvised lung model. The learners were tasked to collect and analyse data related to how the heartbeat's tempo impacted breathing patterns, as witnessed on the chalkboard.

Snapshot of teaching scenario B: Exploring how light reflects off surfaces



Observations made by the Researcher:
In this teaching scenario, the learners could investigate how a mirror alters how light travels. The investigation allowed the learners to recognise that light travels a straight line if reflected off a mirror. A closer look at the image shows that the learners could track the light reflection by aligning it to the toothpicks pinned on a sheet of paper pasted on cardboard. This allowed the learners to realise that light travels straight line, explaining why shadows have the same shape as the objects that cast them. Here, the light reflected off the mirror perfectly aligned with the toothpicks pinned on a sheet of paper pasted on cardboard.

6. Discussion of findings

In the context of teacher education, the expectation is that pre-service teachers specialising in the teaching of Natural Science education ought to develop the skill to teach Natural Science subject matter creatively and practically (Aadland, Espeland & Arnesen, 2017). One such teaching skill includes pre-service teachers adopting a model-based teaching approach as part of their lesson design and delivery (Peel et al., 2019). A common feature of a model-based teaching approach includes pre-service teachers' ability to infuse models as part of their teaching delivery to ensure that learners make that critical link between abstract science concepts and real-time visualisation (Nkambule & Mukeredzi, 2017). For this reason, Dare et al. (2019) claim that a model-based teaching approach allows for a more simplistic understanding of biological, physical and chemical phenomena.

Unfortunately, given the learning benefits of using a model-based teaching approach, it has been reported that middle-schools in the Northern Cape province, which are situated in rural- and disadvantaged areas, are plagued with ill-resourced science classrooms (Mzuza & Van der Westhuizen, 2019). This, as a result, impacts negatively on the ability of science pre-service teachers to follow a model-based teaching approach, since science models in these classrooms are either non-existent, outdated, or irrelevant to the current Natural Science school curriculum (Du Plessis & Mestry, 2019; Mabasa & Singh, 2020; Mtsi & Maphosa, 2016).

This paper was concerned with the issue associated with a lack of science-teaching models available to final-year pre-service teachers during a teaching practicum opportunity. The study aimed to describe how a team of final-year pre-service teachers followed the process of improvisation to develop and utilise improvised science-teaching models during a teaching practicum experience. The paper explores how the process of improvisation that is characterised by the principles of "inspiration", "ideation", and "implementation" enabled the pre-service teachers to develop improvised science-teaching models from low-cost and recycled goods. Moreover, this paper also described the extent to which the pre-service teachers were able to utilise these improvised teaching models as part of their model-based teaching.

Guided by a conceptual understanding of the process of improvisation, this paper shares empirical evidence of how the pre-service teachers followed the principle of inspiration, which is considered as the first step towards the process of improvisation. The principle of inspiration serves as a space that allows for identifying and clarifying individually identified needs and the drive towards the search for a solution (Philip, 2019). In pursuit of the principle of inspiration, the pre-service teachers in the first instance confronted the lack of teaching models in selected schools where they were placed to perform their teaching practicum duties. The issue was made clear in several spontaneous e-mail communications, which included phrases such as "I am already worried because the class does not have any models for us to use - Participant 5" and "I plan my NS [Natural Science] lesson the day before just to find out that no models are available - Participant 3" that was communicated to the module lecturer.

The confirmation of this particular challenge paved the way towards the realisation that something had to be done to address the issue at hand. This critical step towards searching for a solution serves as the final key feature of the principle of inspiration (Aadland, Espeland & Arnesen, 2017). Phrases such as "Aren't there any way to deal with this? - Participant 7" and "we can look around for stuff to use and just do it ourselves - Participant 3" and "at least the kids will see - Participant 3" are indicative of their intention to design their improvised teaching models to support their model-based teaching. Moreover, the phrase "look around for stuff to use and just do it ourselves" suggest that the teaching models will be developed from low-cost materials such as plastics, cardboard, straws, tin cans, to name but a few.

Given the reality of ill-resourced science classrooms in selected South African middle-schools (Mtsi & Maphosa, 2016; Mupira & Ramnarain, 2018) and the pre-service teachers' drive to develop their teaching models, it is not surprising that South African educational policy documents such as the National Curriculum and Policy Statement (DBE, 2011) call on both pre-and in-service Natural Science teachers to acquire the skill of improvisation that would enable them to develop teaching models that would complement their science-teaching. Ramnarain (2020) takes it a step further by suggesting that the skill of improvisation should be regarded as a key Natural Science teacher attribute, which implicates how initial teacher education programmes develop pre-service teachers for the teaching profession.

Furthermore, this paper provided evidence of how the pre-service teachers adhered to the principle of ideation as the second principle that informs improvisation. The principle of ideation enables individuals to distil ideas into insights that could serve as potential strategies to circumvent the needs identified (Aina, 2013; Aadland, Espeland & Arnesen, 2017). The pre-service teachers were able to put their creative ideas and insights into motion through developing some science-teaching models. Although primary and simplistic in design, these models were showcased in figures 1 to 4 and represented the plant cell, the water cycle, the DNA double helix structure, and the lung model. A closer look at these models concurs with some researchers' understanding of science-teaching models when it is regarded as objects that promote the visualisation of complex science phenomena (Dare et al., 2019). The pre-service teachers' models allow the invisible (the DNA structure and the plant cell) to become visible through representation (Taber, 2017).

Finally, the paper provided evidence of how the pre-service teachers followed the implementation principle, which is regarded as the final principle of the improvisation process. The principle of improvisation enables the educator to ultimately put their designs to the test in a real-life teaching context (Aina, 2013), as witnessed in teaching scenarios A and B. The use of photo-voice methodology provided substantial evidence of how a couple of pre-service teachers could infuse the science-teaching models they created. To be specific, a closer look at teaching scenario A points to aspects of a model-based teaching approach.

This approach was linked to the pre-service teacher's ability to engage learners in a learning experience that required them to demonstrate how the respiratory system functions by using a lung model. Another example of a model-based teaching approach surfaced when the learners were tasked to investigate how light reflects off a mirror on a piece of cardboard, thus obtaining a more informed understanding of the topic "refraction of light" (see teaching scenario B). These basic examples of model-based teaching suggest that learners might have been involved in cooperative and collaborative learning. Considering the evidence provided that learners acquired knowledge from their fellow peers instead of relying solely on the instructional delivery of knowledge from the pre-service teacher (see teaching scenario A).

7. Conclusion

The purpose of the study was to describe how a team of final-year pre-service teachers followed the process of improvisation to develop and utilise improvised science-teaching models during a teaching practicum experience. This was done to promote the pre-service teachers' quality of model-based teaching. The need for this study arises from the challenge associated with the lack of science-teaching models available to the pre-service teachers during school visitation opportunities. The pre-service teachers' ability to demonstrate improvisation skills towards developing science-teaching models benefited their quality of Natural Science teaching and impacted the learners' Natural Science learning experience.

In turn, the use of improvised science-teaching models allowed learners to engage in a learning experience that is more "hands-on" and exploratory. Such a learning approach simplified the learners' understanding of Natural Science topics such as plant cell anatomy and genetics and promoted their interest in these topics. As a result, they could physically observe the different model structures (for instance, the helix shape of the DNA molecule, nucleotide pairs that forms part of the DNA structure and the different organelles that make up the plant cell).

This study holds a series of implications for future research in the field of Natural Science teacher education. Given the reality of ill-resourced Science classrooms in selected schools in the Northern Cape province (Mzuza & Van der Westhuizen, 2019), initial teacher education programmes should render environmental and contextual consciousness through shaping pre-service teachers for the diverse schooling contexts. Against this backdrop, initial teacher education programmes should be intentional towards structuring module course material to make the skill of improvisation accessible to pre-service teachers as part of their teacher development.

Future research is needed on how improvisation could assist pre-service teachers' model-based teaching in the different areas of specialisation such as Mathematics, Geography and Technology education. In addition, future research could also attempt to investigate what the pre-service teachers' perspectives are towards utilising improvised teaching models in the teaching and learning environment.

Acknowledgements

I want to thank the University of the Free State for allowing me to write this paper for my PhD project. I also want to thank Prof Micheal Van Wyk and Dr Boitumelo Moreeng, whose guidance, patience and enthusiasm enabled me to believe, try and succeed in completing this paper.

8. References

Aadland, H., Espeland, M., & Arnesen, T. E. (2017). Towards a typology of improvisation as a professional teaching skill: Implications for pre-service teacher education programmes. *Cogent Education*, *4*(1), 12-34. https://doi.org/10.1080/2331186X.2017.1295835

Aina, K. J. (2013). Instructional materials and improvisation in physics class: Implications for teaching and learning. *Computer*, *2*(20), 8-19. https://doi.org/10.1080/0c96053b709495aa8b000000

Akuma, F. V., & Callaghan, R. (2016). Framework for reducing teaching challenges relating to improvisation of science education equipment and materials in schools. *Eurasia Journal of Mathematics, Science & Technology Education, 12*(10), 2697-2717. https://doi.org/10.12973/eurasia.2016.1305a

Barbara, S., & Sam, A. (1957). Improvised apparatus for the determination of specific heat. *American Journal of Physics*, *25*(7), 494-494. https://doi.org/10.1119/1.1934525

Black, M. (1962). Models and Metaphors. (Ithaca, NY: Cornell University Press). https://doi.org/10.11239/1.34345365

Borko, H., & Livingston, C. (1989). Cognition and Improvisation: Difference in mathematics instruction by expert and novice teachers. *American Educational Research Journal*, *26*(4), 473–498. https://doi.org/10.3102/00028312026004473

Bryce, C. M., Baliga, V. B., De Nesnera, K. L., Fiack, D., Goetz, K., Tarjan, L. M., Wade, C. E., Yovovich, V., Baumgart, S., Bard, D. G., & Ash, D. (2016). Exploring models in the biology classroom. *The American Biology Teacher*, *78*(1), 35-42. https://doi.org/10.1525/abt.2016.78.1.35

Creswell, J. W., & Creswell, J. D. (2017). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications.

Damelin, D., Krajcik, J.S., Mcintyre, C., & Bielik, T. (2017). Students making systems models. *Science Scope*, *40*(5), 78-83. https://doi.org/10.12973/eurasia.2017.1355

De Bruin, L. R. (2019). The use of cognitive apprenticeship in the learning and teaching of improvisation: Teacher and student perspectives. *Research Studies in Music Education*, *41*(3), 261-279. https://doi.org/10.1177/1321103X18773110

Dare, E. A., Ring-Whalen, E. A., & Roehrig, G. H. (2019). Creating a continuum of STEM models: Exploring how K-12 science teachers conceptualise STEM education. *International Journal of Science Education*, *41*(12), 1701-1720. https://doi.org/10.1080/09500693.2019.1638531

Department of Basic Education (DBE). (2011). *Curriculum and assessment policy statement. Intermediate phase Grades 4–6: Natural sciences and technology*. Pretoria, South Africa: DBE. https://doi.org/10.17159/2221-4070/2018/v7i0a7

Department of Higher Education and Training (DHET). (2015). *Policy on the Minimum Requirements for Teacher Education Qualifications, as revised 2014*. Pretoria: Government Gazette. https://doi.org/10.35279/-297730/2015/552

Du Plessis, P., & Mestry, R. (2019). Teachers for rural schools - A challenge for South Africa. *South African Journal of Education, 39*(2), 14-32. https://doi.org/saje.v39ns1a1774

Erickson, F. (1982). Classroom discourse as improvisation: Relationships between academic task structure and social participation structure in lessons. In L. C. Wilkinson (Ed.), Communicating in the classroom (pp. 153 – 181). New York: Academic Press. https://doi.org/ci.nii.ac.jp/naid/10020917973

Eze, P. I. (2018). Effectiveness of improvisation of instructional materials on students' academic achievement and retention in Christian religious studies. *Educational Studies*, *5*(2), 33-39. https://doi.org/10.3102/00028312026004473

Fleischmann, E. M. L. & Van der Westhuizen, C. P. (2017). The Interactive-GIS-Tutor (IGIST): An option for GIS teaching in resource-poor South African schools. *South African Geographical Journal, 99*(1), 68-85. https://doi.org/10.1080/03736245.2016.1208576

Gobert, J. D. & Buckley, B. C. (2000). Introduction to model-based teaching and learning in science education. *International Journal of Science Education*, *22*(9), 891-894. https://doi.org/10.1080/095006900416839

Harlow, D. B. (2010). Structures and improvisation for inquiry-based science instruction: A teacher's adaptation of a model of magnetism activity. *Science education*, *94*(1), 142-163. https://doi.org/10.1002/sce.20348

Holdhus, K., Høisæter, S., Mæland, K., Vangsnes, V., Engelsen, K. S., Espeland, M., & Espeland, Å. (2016). Improvisation in teaching and education - roots and applications. *Cogent Education, 3*(1), 1-17. https://doi.org/10.1525/abt.2016.78.1.35

Hickey, M. (2015). Learning from the experts: A study of free-improvisation pedagogues in university settings. *Journal of Research in Music Education, 62*(4), 425-445. https://doi.org/10.1177/0022429414556319

Ingham, A. M., & Gilbert, J. K. (1991). The use of analogue models by students of chemistry at higher education level. *International Journal of Science Education,* 13(3), 193-202. https://doi.org/10.1080/0950069910130206

Mabasa, T., & Singh, S. (2020). Decolonising continuing teacher professional development in the teaching of physical science through improvisation in rural areas. *South African Journal of Higher Education*, *34*(3), 146-163. https://doi.org/10.20853/34-3-3455

Mtsi, N., & Maphosa, C. (2016). Challenges encountered in the teaching and learning of the natural sciences in rural schools in South Africa. *Journal of Social Sciences*, *47*(1), 58-67. https://doi.org/10.1080/09718923.2016.11893544

Munje, P. N., & Jita, T. (2020). The Impact of the Lack of ICT Resources on Teaching and Learning in Selected South African Primary Schools. *International Journal of Learning, Teaching and Educational Research*, *19*(7), 263-279. https://doi.org/10.26803/ijlter.19.7.15

Mupira, P., & Ramnarain, U. (2018). The effect of inquiry-based learning on the achievement goal orientation of grade 10 physical sciences learners at township schools in South Africa. *Journal of Research in Science Teaching*, *55*(6), 810-825.

Mzuza, M. K., & Van Der Westhuizen, C. P. (2019). Review on the state of GIS application in secondary schools in the Southern African region. *South African Geographical Journal*, *101*(2), 175-191. https://doi.org/10.1002/tea.21440

Nkambule, T., & Mukeredzi, T. G. (2017). Pre-service teachers' professional learning experiences during rural teaching practice in Acornhoek, Mpumalanga Province. *South African Journal of Education, 37*(3), 25-39. https://doi.org/10.15700/saje.v37n3a1371

Okori, O. A., & Jerry, O. (2017). Improvisation and utilisation of resources in the teaching and learning of science and mathematics in secondary schools in Cross River state. *Global Journal of Educational Research, 16*(1), 21-28. https://doi.org/10.4314/gjedr.v16i1.4

Ozuah, A. C. (2019). Assessment of the extent of improvisation in teaching and learning basic science in upper basic school level in Anambra east local government area of Anambra state. *International Journal of Novel Research in Science, Technology and Engineering, 2*(1), 14-29. https://doi.org/10.12973/eurasia.2016.1305a

Pareek, R. B. (2019). An assessment of availability and utilisation of laboratory facilities for teaching science at secondary level. *Science Education International, 30*(1), 75-81. https://doi.org/10.1080/0950069910130206

Peel, A., Zangori, L., Friedrichsen, P., Hayes, E., & Sadler, T. (2019). Students' model-based explanations about natural selection and antibiotic resistance through socio-

scientific issues-based learning. *International Journal of Science Education, 41*(4), 510-532. https://doi.org/10.1080/09500693.2018.1564084

Perkins, D. N. (1986). Knowledge as Design. (Hillsdale, NJ: Lawrence Erlbaum Associates). https://doi.org/https://stars.library.ucf.edu/cirs/3272/

Philip, T. M. (2019). Principled improvisation to support novice teacher learning. *Teachers College Record, 121*(4), 4-18. https://doi.org/10.693/533570693.2019.345584

Ponzio, N. M., Alder, J., Nucci, M., Dannenfelser, D., Hilton, H., Linardopoulos, N., & Lutz, C. (2018). Learning science communication skills using improvisation, video recordings, and practice, practice, practice. *Journal of microbiology & biology education, 19*(1), 13-31. https://doi.org/10.1128/jmbe.v19i1.1433

Ramnarain, U. D. (2020). Exploring the Autonomy of South African School Science Students when Doing Investigative Inquiries for a Science Fair. *Eurasia Journal of Mathematics, Science and Technology Education, 16*(12), 11-19. https://doi.org/10.29333/ejmste/9128

Sawyer, R. K. (2004). Creative teaching: Collaborative discussion as disciplined improvisation. *Education Researcher, 33*(2), 15-32. https://doi.org/10.3102/0013189X033002012

Sawyer, R. K. (2011). What makes good teachers great? The artful balance of structure and improvisation. In R.K. Sawyer (Ed.), Structure and improvisation in creative teaching (pp. 1–24). Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9780511997105

Seel, N. M. (2017). Model-based learning: A synthesis of theory and research. *Educational Technology Research and Development, 65*(4), 931-966. https://doi.org/10.1007/s11423-016-9507-9

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*(1), 1–22. https://doi.org/10.17763/haer.57.1.j463w79r56455411

Singh, S. K., & Singh, R. J. (2012). Pre-service teachers' reflections of South African science classrooms. *South African Journal of Higher Education,* 26(1), 168-180. https://doi.org/10.10520/EJC123969

Stears, M., & James, A. (2011). Towards socially responsible biology: Two cases in a teacher education programme. *African Journal of Research in Mathematics, Science and Technology Education, 15*(3), 122-136. https://doi.org/10.1080/10288457.2011.10740722

Taber, K. S. (2017). Models and modelling in science and science education. In *Science education*. Brill Sense. https://doi.org/ 9789463007498/BP000021

Tsybulsky, D., Dodick, J., & Camhi, J. (2018). High-school students in university research labs? Implementing an outreach model based on the science as inquiry approach. *Journal of Biological Education, 52*(4), 415-428. https://doi.org/10.1080/00219266.2017.1403360

Wrigley, C., & Straker, K. (2017). Design thinking pedagogy: The educational design ladder. *Innovations in Education and Teaching International, 54*(4), 374-385. https://doi.org/10.1080/14703297.2015.1108214

Yeboah, R., Abonyi, U. K. & Luguterah, A. W. (2019). Making primary school science education more practical through appropriate interactive instructional resources: A case study of Ghana. *Cogent Education, 6*(1), 1-14. https://doi.org/10.1017/CBO9780511997105

Yinger, R. J. (1987). By the seat of your pants: An inquiry into improvisation and teaching. Paper presented at the annual meeting of the American Educational Research Association, Washington, DC. https://doi.org/10.2244/abt.2016.78.1.35