AUTHORS:
Mrs Cherine Jackson[1]
Prof Josef de Beer[1]
Dr Lounell White[1]

AFFILIATION:
[1]Research Unit Self-Directed Learning, North West University

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THE AFFECTIVE AFFORDANCES OF FRUGAL SCIENCE USING FOLDSCOPES DURING A LIFE SCIENCES WATER QUALITY PRACTICAL

ABSTRACT

Manu Prakash, the developer of the foldscope microscope reported on in this paper, stated that it is important to use tools that can support open-ended inquiry in the classroom, without dumbing down those tools. Scientific equipment in the school laboratory is often very expensive and only available to those who can afford it. "Frugal science" is a trend in education that researches, develops and introduces economical and quality scientific resources to developing countries. In South Africa, many underprivileged schools lack quality practical and laboratory resources to perform simple tasks, such as microscopy. Furthermore, the absence of laboratory investigations could lead to learners not enjoying Life Sciences nor developing a more nuanced understanding of the nature (tenets) of science. As part of an indigenous knowledge intervention hosted by the North-West University, teachers were provided with $1 foldscopes (paper microscope) to use in their classrooms. This research reports on the views of Life Sciences learners and teachers on the use of foldscopes in the Life Sciences classroom during a practical lesson. The focus of the research is to illuminate how such problem-based approaches could enhance affective outcomes. This generic qualitative research study has elements of design-based research (DBR) as well as classroom action research (CAR), carried out by participating teachers to investigate the affordances of foldscopes. Data was collected using observations, teacher reflections, learner reflections, photographs and personal interviews. From an affective stance, this qualitative study used Engeström's third-generation Cultural-Historical Activity Theory (CHAT) as a research lens in order to identify factors that promote or inhibit the use of foldscopes in the Life Sciences classroom during a practical lesson.

Keywords: *affective domain, classroom action research, foldscopes, frugal science, pedagogical content knowledge, self-directed learning and teacher professional development.*

1. INTRODUCTION AND PROBLEM STATEMENT

According to the World Economic Forum's competitive index for 2017 to 2018, South African mathematics and science education is ranked 128th out of 137 countries (Schwab, 2018). The 2019 report highlights that sub-Saharan Africa is globally the least competitive region, though South Africa did improve to the second most competitive country in the region, after Mauritius (World Economic Forum, 2019). One of the educational issues that teachers in the Life Sciences classroom face is that some learners do not enjoy, engage or prosper academically in Life Sciences as a subject (Hidi & Harackiewicz, 2000). Researchers such as De Beer (2014) and Buma (2018) call the marginalisation of the affective domain in the science classroom as the “missing link” and suggest that teachers should consciously teach for the affective domain. We would like to echo the words of Rotherham and Willingham (2010:17) who, in a slightly different context, argued that the teaching of certain skills and aptitudes are often “a matter of chance rather than the deliberate design of our school system… we cannot afford a system in which receiving a high-quality education is akin to a game of bingo”. Hidi and Harackiewicz (2000:151) identified two factors that inhibit learner academic performance and interest in the classroom, namely “lack of ability” and “lack of effort”. These factors inhibit affective learning in the classroom. Learners might find various topics in Life Sciences too difficult, or learners might find the teacher or topic too boring (Pretorius, 2015). Many teachers still use content-based, conventional, transmission-mode teaching methods such as “chalk-and-talk” (Riga *et al*., 2017), which does not favour “out-of-the-box thinking” and autonomous learning (Farahani, 2014). This should also be seen in the light of research by Ramnarain and Schuster (2014) that showed that teachers often replace open-inquiry approaches with transmission-mode and teacher-centred approaches (and “teaching-to-the-test”), due to systemic pressure, e.g., from parents and principals for good examination results.

Inquiry-based (heuristic) methods are not a new approach to teaching Life Sciences (Riga *et al*., 2017). Heuristic methods allow teachers and learners to have a sense of discovery and enhance their own sense of learning (becoming a self-directed learner). This concept is also commonly known as the “Armstrong Method” (Riga *et al*., 2017:247). Scientific methods and skills cannot be taught using transmission-mode teaching, but rather hands-on practical and self-discovery methods. Many teachers neglect using practical-based teaching or problem-based learning as well as cooperative strategies (Jacobs, De Beer & Petersen, 2016) because teachers feel they may be taken out of their comfort zones. Furthermore, some teachers do not have a comprehensive understanding of the nature of science (Ogunniyi, 2002). Teachers may also avoid problem-based learning as they are not confident or comfortable in conducting hands-on practical sessions with learners (De Beer & Petersen, 2016). Many studies have been done to indicate that teachers avoid problem-based learning and cooperative learning (Cronje, 2015; De Beer, 2017) due to a full curriculum and time constraints (Pretorius, 2015), as well as systemic pressure (Ramnarain & Schuster, 2014).

Another issue in South African education is the lack of quality resources including practical equipment in the Life Sciences classroom (Cronje, 2015; Jacobs, 2015; Pretorius, 2015). Consequently, there is a need for quality “shoestring approaches” (De Beer & Petersen, 2016) or “frugal science” (Ahuja, 2014). Teacher agency requires constructive thought processing, and improvisation of various approaches, in order to achieve the aims of the content in the Life Sciences curriculum. Consequently, teachers were introduced to foldscopes during indigenous knowledge interventions held by the North-West University. A foldscope is a microscope that was developed by Stanford University (Cybulski *et al*., 2014). During the interventions, teachers were invited to develop their own practical activities; hence, the importance of exposing teachers to classroom action research (CAR).

Many researchers find ways for Life Sciences teachers to improve on the teaching of science in context. However vital resources are required to teach science (Pretorius, 2015). Many schools or Life Sciences teachers do not have these resources, which is part of the enormous challenge South African education is facing. Therefore, teachers need to use every opportunity to identify cheaper, alternative ways to improve their practice (De Beer & Petersen, 2016).

The focus of this research was to investigate affective gains among learners and teachers, who engaged with foldscopes and CAR. More detail regarding the affective domain and conceptual orientation is discussed under Krathwohl's taxonomy of the affective domain later in this article.

2. LITERATURE REVIEW

2.1 Pedagogical content knowledge and an understanding of the nature of science

According to Shulman (1987:8), pedagogical content knowledge is the "blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organised, represented, and adapted to the diverse interests and abilities of learners and presented for instruction". Many studies suggest that teachers do not have sufficient Life Sciences pedagogical content knowledge due to poor content and poor pedagogical knowledge (Schneider & Plasman, 2011). Part of a Life Sciences teacher's pedagogical content knowledge should be a good understanding of the tenets of the nature of science. Abd-El-Khalick, Bell and Lederman (1998) mention that there is a relationship between teachers' views on the nature of science and how they teach. Teachers need a good understanding of the nature of science in order to accurately portray these tenets in their pedagogy. Therefore, there is a need for consistent and continuous professional development interventions (Cronje, 2015; Pretorius, 2015). In response to this, the North-West University designed a professional development intervention concerning indigenous knowledge. The intervention had a variety of design principles that allowed for the growth of various skills among the teachers, including pedagogical content knowledge and the competency to conduct action research in their classrooms.

2.2 Affective domain

The affective domain as a learning domain has been neglected by the education community (Garritz, 2010). The cognitive domain is central in education, yet the affective domain (values and attitudes, e.g., perseverance, tolerance, etc.) is a driver for cognitive development. Research in neuroscience (Dubinsky, Roehrig & Varma, 2013) shows that experiences with an emotional flavour are more likely to be committed to memory.

The affective domain includes the perceptions, interests, attitudes, values and emotions of the teachers and learners (Birbeck & Andre, 2009; Clark & Price, 2016). Krathwohl's taxonomy was used as an intermediary theory to see if any affective learning took place during the water practical using the foldscopes. There are five affective categories that indicate internalisation. These include receiving, responding, valuing, organisation and characterisation by a value complex (Krathwohl, 1964; Lynch, Russell, Evans & Sutterer, 2009).

2.3 Teacher professional development

The idea of teacher professional development is to assist, build and support teachers' professional learning (Warford, 2011) and capability regarding pedagogical content knowledge, skills and effectiveness as a teacher (Fraser, Kennedy, Reid & McKinney, 2007). Thus, one of the design principles of the intervention included the incorporation of CAR as part of the programme. The notion of the "teacher as a learner" sheds light on teacher professional development, which creates opportunities for teachers to learn more about a specific topic and to continue their professional development (Fraser *et al.*, 2007). Teacher professional learning is complex and requires teachers to reflect individually and cooperatively with other teachers (Avalos, 2011). Teachers can share ideas from CAR with other teachers; thus, motivating others as part of a community of practice. Teachers should adopt a practice of lifelong learning, which in turn will enhance continued professional development.

2.4 Classroom action research (CAR)

Gravett and De Beer (2015:344) explain CAR as "more data-based and systematic than reflection, but less formal and controlled than traditional educational research". During the intervention on infusing indigenous knowledge into the Life Sciences classroom, teachers were trained to engage in CAR. This CAR centred on the use of foldscopes in the classroom and the affordances of this method.

There are various steps (Figure 1) that should be followed during the CAR cycle. Firstly, teachers are required to identify a problem in the classroom. In this case, the problem that two participating teachers identified was the lack of learner curiosity about, and interest in, the topic Ecology (Pretorius *et al.*, 2014). Secondly, teachers are required to plan their research. In this case, the two teachers planned a water quality assessment project using the foldscopes.

Thirdly, the teacher must act and collect data. During the water quality activity, learners completed the practical handout, which was then analysed and evaluated.

Reflection cannot be excluded from CAR, and teachers must continually reflect during the lesson as well as during the entire CAR. These reflections were also analysed and are reported on in this paper. Such reflection can assist teachers to become self-directed learners (SDL) (Knowles, 1975) and agents of change (Van der Heijden, Geldens, Beijaard & Popeijus, 2015).

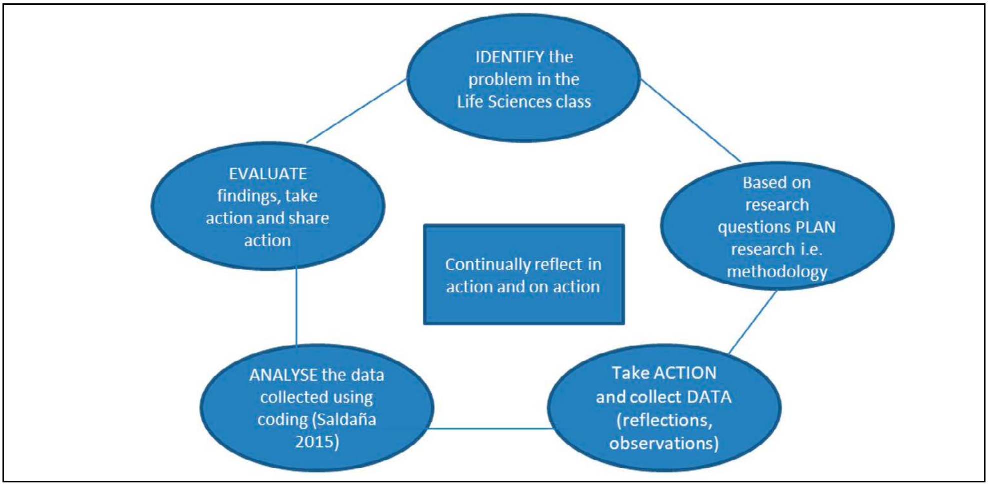

Figure 1: The CAR cycle adapted from Gravett and De Beer (2015:347)

2.5 Frugal science and foldscopes

Many South African schools do not have the privilege of quality school resources (Mampane & Bouwer, 2011) including laboratory equipment for practical work in the Life Sciences classroom. “Frugal science” is a concept in education that introduces cheap, accessible scientific educational tools within developing countries (Ahuja, 2014). The foldscope is a low-cost optical paper microscope that was designed and developed by Manu Prakash and his students at the Stanford University School of Medicine (Ahuja, 2014). The paper foldscope can magnify up to 2000 times, which is greater than the common light (compound) microscope (400 times); thus, exposing greater detail when viewing unicellular organisms. The foldscope is also portable and does not require electricity. The foldscope is ideal for fieldwork and an affordable and useful tool for schools that do not have the resources for practical lessons.

The foldscope can provide learners, who do not have access to light (compound) microscopes, with practical skills as well as the opportunity to view the unicellular world (Cybulski *et al.*, 2014). Following instructions, the paper foldscope can easily be assembled by folding various cardboard parts (including a 2000X lens). Teachers can easily design hands-on activities (part of their CAR) using the foldscope while also infusing indigenous knowledge into Life Sciences lessons. As shown in the CHAT diagram (Figure 2), this was the object of the research project reported on in this paper.

3. AIM, OBJECTIVES AND RESEARCH QUESTIONS

3.1 Aim

The aim of the research reported on in this paper was to explore the affordances of the implementation of foldscopes during two teachers’ action research projects.

3.2 Research questions

The two research questions that guided this research were:

1. What are the affordances of utilising foldscope microscopes in promoting affective outcomes in the Life Sciences classroom?
2. What are teachers’ experiences of engaging in classroom action research (CAR) on foldscopes, and what are the affective affordances of such CAR?

4. RESEARCH DESIGN, RESEARCH METHODS AND THEORETICAL FRAMEWORK

As part of a Master’s dissertation, this research followed a generic qualitative approach (Creswell, 2013; Merriam & Tisdell, 2015). This research also has elements of DBR as well as CAR, as carried out by participating teachers after the intervention. After Cycle 1 of the larger National Research Foundation (NRF) project, the data showed that teachers could benefit from engaging in CAR. Therefore, CAR was included in later interventions. This research focused on two teachers’ experiences of engaging with CAR based on the affordances of the foldscopes for affective development.

5. THEORETICAL FRAMEWORK

The theoretical framework followed epistemological models to allow the researcher to interpret the data from the CAR projects.

5.1 Theoretical framework

This research used social constructivism as the theoretical orientation. Social constructivist discourses allowed the researcher to make sense of learner and teacher experiences during the water quality investigation (Seimears *et al*., 2012). Social constructivism has its roots in the developmental theory of Vygotsky and his well-known construct, the zone of proximal development (Vygotsky, 1978). Social constructivism is based on how people understand and construct their cultural and social reality to create meaning (Kim, 2001). Furthermore, activity theory was used for further analysis of the data using Engeström third-generation Cultural-Historical Activity Theory (CHAT) (Engeström, 2009) on an interpersonal plane.

Therefore, as suggested by Engestrom (2009), we used CHAT by juxtaposing two interdependent activity systems – the teacher's teaching activities compared to the learner's learning activities (Figure 2). Within the classroom two different, but related, activity systems were compared with each another to identify any tensions or contractions within the activity system. Although the teacher is teaching in a classroom setting, it does not necessarily mean that the learner is learning (Brown, 2003). Therefore, the use of CHAT on an interpersonal plane (Mentz & De Beer, 2017) allowed the researcher to identify the affective outcomes of the foldscope activities. The different nodes of a third-generation activity system include the *subject* (S), *object* (O), *tools* (T), *community* (C), *rules* (R) and *division of labour* (D) (Engeström, 2000).

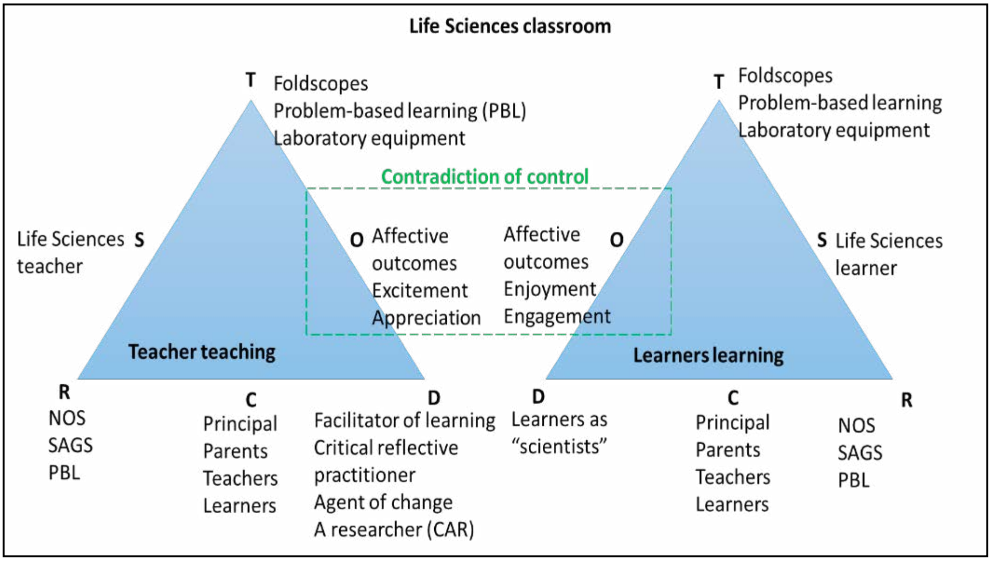

Figure 2: Using third-generation CHAT in an unconventional way by comparing the Life Sciences teacher and learner (adapted from Engeström, 1987; and De Beer & Mentz, 2017)

The first triangle in Figure 2 shows the Life Sciences teacher as the *subject* and the second triangle shows the Life Sciences learner as the *subject*. The *tools* that the teacher and learners used for the CAR projects include the foldscopes, educational equipment and laboratory equipment. The activity system is guided by *rules*, namely, the nature of science (the learners complete a practical activity that uses scientific methods); the Subject Assessment Guidelines

(SAGS) (IEB, 2018) or Curriculum Assessment Policy Statement (CAPS) (Department of Basic Education, 2011); as well as the *rules* of problem-based learning. The *community* include the principal, parents, teachers and learners.

The principal granted permission to conduct research in the classroom and parents were required to take their children to the nearest water source (dam or river) to collect water for the foldscope practical activity (fieldwork). The *division of labour* in Triangle 1 includes the teacher as a facilitator of learning, critical reflective practitioner, agent of change and researcher (CAR). The division of labour among the learners include their role as "scientists" conducting fieldwork and using scientific methods. The *object* in this activity system is the achievement of affective outcomes from the learning activity, namely, enjoyment, excitement, appreciation and engagement. Engeström (2009) emphasises that the *object* should be permeated into the activity system. Furthermore there is complexity in the object called the *contradiction of control* (McNeil, 2013). In an ideal context there should be a shared view to achieve the object (Mentz & De Beer, 2017).

5.2 Krathwohl's taxonomy of the affective domain

Krathwohl's taxonomy was used as an intermediary theory to see if any affective learning took place during the water practical using the foldscopes. There are five affective categories that indicate internalisation. These include *receiving, responding, valuing, organization* and *characterization* by a value complex (Krathwohl, 1964; Lynch *et al.*, 2009).

As seen in Figure 3 below, there are varying degrees of affective learning that can occur. These proceed from simple to complex affective learning (Buma, 2018). According to Krathwohl (1964), the simplest affective learning trait is *receiving*, which includes awareness and willingness to respond to the water quality project. The second affective learning trait is *responding*, which relates to the degree of involvement in the learning activity. The third affective learning trait is *valuing,* which relates to appreciation of the learning activity. The fourth affective learning trait is *organization,* which prioritises the aim of the learning activity. Lastly, the most complex affective learning trait is *characterizing by a value*, which includes complete internalisation of the value set, i.e., "responsible and ethical use of science knowledge in the service of humanity" (Buma, 2018:106). This set of criteria was used to analyse the data collected from the CAR projects.

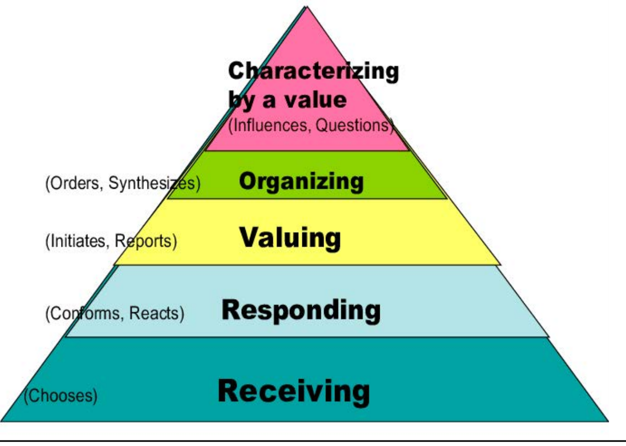

Figure 3: Krathwohl's Taxonomy of Affective Learning (Neuman & Friedman, 2010)

6. METHODOLOGY

One of the design principles that was distilled from the larger NRF-funded DBR research project was to inspire teachers to engage in CAR. This allowed teachers to research and design problem-based activities. Gravett and De Beer (2015) define CAR as a methodology that is midway between unstructured teacher reflection and formal and structured traditional educational research.

As part of the indigenous knowledge intervention, teachers received foldscopes to use in their classroom. Two enthusiastic teachers were selected after the intervention to conduct an action research activity with their Life Sciences class. The activity was using the foldscopes to assess the quality of water in South Africa (on a very small scale).

In this case, the two teachers planned a water quality project using the foldscopes. The teachers identified the theoretical framework as social constructivism (Powell & Kalina, 2009). The conceptual framework is related to the affective domain, as it is important to see if learners affectively embraced their learning during the practical, and to see if learning occurred. Teachers were instructed on the affective domain during the interventions. The research approach used was generic qualitative research, because data collection involved observation, artefacts and learner and teacher reflections. The methodology included how the participants were selected and how the activity was conducted, which will be explained later. Ethical considerations were vital, and the teachers, being employees at the school, had to obtain consent from the learners and parents.

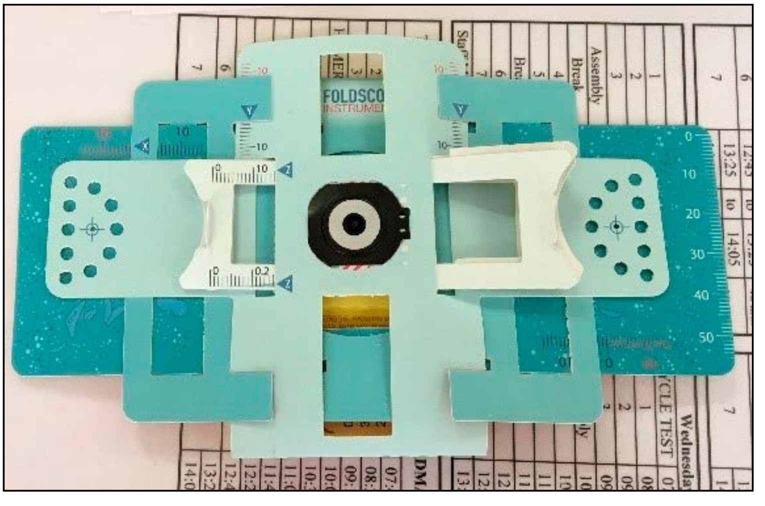

Figure 4: Completed foldscope assembled by one of the learners

The water quality activity was conducted, and learners completed the practical handout, which was then analysed. The data was transcribed and coded by the researcher to determine the affordances of the foldscopes. The foldscope activity consisted of two components. Firstly, learners had to conduct fieldwork, whereby they had to collect a water sample from a dam or river close to their home, observe their surroundings and test the pH and the temperature of the water. Learners had to further test the water samples in the classroom (practising their laboratory/practical skills), including testing pH, temperature and the ammonia test.

Learners had to fold the foldscopes carefully following the instructions provided. After folding the foldscope learners were required to make slides from their water samples in order to view unicellular or multicellular organisms. Finally, learners had to complete the practical write-up that included writing reflections.

6.1 Sampling

It was important to select participants who were willing to share their CAR experiences. Therefore, a purposeful sampling strategy was used (Creswell, 2013). The participants were experienced high school Life Sciences teachers who attended the indigenous knowledge intervention held by the North-West University.

6.2 Ethical considerations

The North-West University Faculty of Education Ethics Committee provided ethical clearance (Ethics clearance number NWU-00357-18-A2). First, the principal was notified about the classroom visit and the purpose of the research. Consent and permission forms were handed out to the teachers and learners involved in the CAR. Teachers and learners were informed that they would remain anonymous and pseudonyms would be used. Parents had to give permission for their children to be part of the research; thus, parents had to sign permission letters.

6.3 Collecting data

Qualitative data instruments were used as well as in the action research projects. These instruments captured real-life experiences (social constructivism) regarding the foldscope activity. The instruments included classroom observations, personal teacher interviews as well as teacher and learner reflections. Teachers were interviewed after the water quality investigation. Teacher and learner reflections were captured. The teachers received a document with questions to guide the reflection process. The learners reflected during the water practical activity, as these questions were embedded in the working document.

6.4 Data analysis

Data from the interviews and reflections were transcribed and analysed using a code-to-theory method (Saldaña, 2015). Themes that emerged are discussed in conjunction with the literature reviewed. Descriptive coding was used in this research. The transcribed data was added to tables and codes were extracted from the information. Codes were organised to form categories and, from the categories, themes emerged.

In-vivo coding was used to include excerpts from the direct speech of the teachers and learners, rather than the codes selected by the researcher; since qualitative research is descriptive and natural responses from participants are preferred (Saldaña, 2015). Emotion coding was also used as it captures affective outcomes. Emotions are part of participants' worldviews and can provide a variety of perspectives (Saldaña, 2015).

6.5 Validity, reliability and trustworthiness

Member checking was used and generated data was taken back to the participants to ensure that what was written reflected their realities. Open-ended reflective questions for the interviews and questionnaires were designed according to the aim of the research, thus strengthening validity. The question items were also reviewed by a panel of experts. According to Thyer (2001), reliability is repeatability and uniformity of data in a similar context yielding similar results. Various details about sample selection, methodology and data analysis must be provided and explained to ensure reliability of the findings. Trustworthiness of qualitative data can be guaranteed through credibility, transferability, dependability and confirmability (Babbie & Moutin, 2002). Trustworthiness can be achieved by ensuring that the results obtained are credible according to the literature and the context of the study, using triangulation.

7. FINDINGS AND DISCUSSION

The following themes emerged from the analyses of the data of the foldscope activity.

7.1 Theme 1: Some learners were frustrated that no "quick-fix" guidelines were provided for the foldscope microscopy activity; and that they had to devise own experimental designs.

Some trends in educational research are learner autonomy (Farahani, 2014) and teaching skills for the 21st century (Kereluik *et al*., 2013). Educational pedagogies are moving towards learner-centred approaches (O'Neill & McMahon, 2005), including: cooperative learning strategies (Johnson & Johnson, 1987); flexible learning (O'Niel *et al*., 2005); experiential learning (Burnard, 1999, quoted by O'Niel *et al*., 2005) and self-directed learning (Knowles, 1975).

Research has shown that teachers do not incorporate learner-centred pedagogies in the Life Sciences classroom due to lack of PCK (Mothwa, 2011); time constrains; a full curriculum and a poor understanding of cooperative learning approaches (confusing it with group work) (Jacobs, De Beer & Petersen, 2016). Ramnarain and Schuster (2014) also show how systemic pressures to "teach-to-the-test" militate against open inquiry and cooperative learning.

Furthermore, learners are unfamiliar with these strategies because some teachers do not implement cooperative strategies in the classroom (Jacobs *et al.,* 2016); thus, learners rely on the teachers to include specific instructions and explain certain concepts, in other words "spoon feeding" for the exam, consequently reducing "out-of-the-box" thinking. Teachers are also constricted to the curriculum (CAPS or SAGS); therefore, the curriculum also reduces agency. We have a system that only wants the correct answers and does not allow for agency. Learner 33 said: "It took a while for me to gain trust in myself, as I didn't want to make a mistake". Teachers are now becoming aware that learners need to be prepared for "life beyond the classroom" (Farahani, 2014). Evidence from this research showed that children are still accustomed to being "spoon fed" because it is very difficult for them to follow instructions on their own. During this CAR, data indicated that learners find lateral thinking very difficult. Learner 1 said: "It was difficult because the instructions weren't specific"; and Learner 2 added that "it was extremely difficult to fold the microscope as the instructions were not very clear and many of the parts looked similar to each other". This gives evidence that learners are accustomed to being "spoon-fed", despite the learner-centred approaches to initiate "self-feeding" (Farahani, 2014).

Learners also realised that they require psychomotor skills to complete this activity. For example, Learner 56 indicated that "folding the foldscope was difficult because it required the use of fine motor skills, something many people lack, it also required careful and meticulous following of instructions within a short time period". Once again such responses suggest that our education system does not allow for self-discovery and "self-feeding"; and shows a lack of awareness and responsiveness towards autonomous learning (Farahani, 2014). Therefore, there is a need for more interventions that include CAR; to enable teachers to become more aware of autonomous learning, for themselves and the learners they teach.

7.2 Theme 2: Learners enjoyed the overall experience of folding the foldscope, and indicated that it was fun, interactive but also challenging

Cognitive dissonance is evident in the data. Festinger (1962:93) explains cognitive dissonance as "two items of information that psychologically do not fit together are said to be in a dissonant relation to each other". In the context of this research, the data shows contradicting expressions from the learners. Learners found the activity very difficult yet rewarding. Learner 7 indicated that "the folding of the foldscope microscope was very interesting and challenging"; and Learner 44 said: "It pushed me out of my comfort zone as normally I do not build things or enjoy making things, but I really enjoyed building the foldscope". Taking learners out of their comfort zone creates a sense of cognitive dissonance. Learners engage with the learning material, but find it challenging; yet towards the end, learners enjoyed it and learnt a lot from the foldscope activity. Learner 27 explained:

> The folding of the foldscope microscope was a challenging, and yet rewarding task – at times I truly struggled to interpret the instructions that were provided on the instruction manual and thus the folding was quite tricky at stages – and yet, it was exhilarating at the same time, every time I folded a piece of the microscope. During certain stages of the folding process, I experienced irritation and agitation due to the fact that I could not achieve the desired outcome/fold the different pieces together in the manner that was depicted on the instruction leaflet.

Not only was the foldscope activity challenging for the learners, but data also shows that learners were fearful of the activity and easily gave up. Teacher 2 indicated that: "Those who persisted did see things but some gave up". Learner 55 indicated the following: "I was just a bit scared that I was going to tear it but if you work carefully you won't".

The quote from Learner 55 above suggests a degree of anxiety regarding the activity, which indicates that teachers don't always give learners hands-on activities to challenge themselves. Teachers often indicate that they have limited time in the classroom to conduct such activities (Cronje, 2015; De Beer, 2017).

7.3 Theme 3: Affective domain is addressed during this hands-on practical

Learners indicated that it was a stimulating and fun task. Another trend in Science, Technology, Engineering and Mathematics (STEM) education is the inclusion of the Arts (STEAM). The inclusion of the Arts has synergy with the notion of *Homo ludens* – the playing human or the pedagogy of play (Huizinga, 1955, quoted by Jautse, Thambe & De Beer, 2016) was evident in the data. Learners 2, 5, 9, 12, 28, 33, 35, 40 and 41 indicated that the foldscope activity was "fun", suggesting that learners really enjoyed the hands-on foldscope activity.

Data shows that the affective domain was evident in this learning opportunity. The affective domain has been described as "penetrating the innermost recess of the heart, affective education attaches greater meaning to what learners learn and makes the overall learning experience more memorable, fulfilling and relevant to the real world" (Green, 2017:36). Learners showed respect, and build relationships, by asking for assistance regarding folding of the foldscope. Learner 7 said: "I found myself asking for help whilst constructing it more than once, my classmates were very helpful and we all tried to help each other if need be".

Furthermore, this activity created a mutual learning zone (cooperative learning); at the same time improving their patience and creativity. Learner 42 remarked: "It allowed us to let lo[o]se, be creative and embrace our inner child". Learners showed awareness and responded well to the task at hand (Level 2 of Krathwohl's taxonomy): "This practical was a fun learning adventure which taught me many new things; it gave me problem solving skills" (Learner 5).

Another affective outcome was that learners showed appreciation for nature: Learner 28 said: "You feel like a proper biologist"; Learner 17 added: "It is eye-opening and almost humbling to realise that a tiny living thing can affect your life drastically".

Learners also showed self-gratification and found it very rewarding, which is another affective outcome. Learners showed value (Level 3 of Krathwohl's taxonomy) towards the foldscope learning activity. Learner 21 said "it looked really cool"; Learner 27 said "the experience was positive and enjoyable"; and Learner 31 said "I had to be very involved and attentive".

Overall, the data indicated that affective learning took place during this foldscope activity. Learners found it new, enjoyable, exciting and fun. In the parlance of Immordino-Yang and Damasio (2007:3), the data showed evidence that the learners and teachers were of the opinion that: "We feel, therefore we learn".

7.4 Theme 4: Learners show an appreciation for the role of Life Sciences in society (CAPS – AIM 3)

The curriculum and assessment policy statement (CAPS) includes three aims, one being appreciating and understanding the history, importance and application of Life Sciences in society (Department of Basic Education, 2011:1). The data indicates that learners showed appreciation for the role of science in society. Learner 5 reflected:

> The foldscope was a valuable tool as it brings microscopes to everyone at a very cheap price, which will end up exposing more people to biology and increase knowledge and learning within schools, the overall prac gave me some insight into how people cause pollution, and how rural people can investigate the quality of their water.

Furthermore, Learner 9 added:

> It gives me great pride to know that under privileged children will soon feel the joy and curiosity one feels when they look down a microscope.

Learner 15 argued that:

> Very often people assume water is safe to drink because the water looks clear which indicates there's nothing in the water. Through the use of the foldscope it was found that there is in fact many organisms that inhabit the water.

Learners have indicated that there is a lack of scientific literacy in the community, but with the use of the foldscope, more people will become aware of scientific reasoning.

7.5 Theme 5: Teacher as a reflective practitioner, researcher and self-directed learner using CAR.

The teachers' reflections indicated that they found the design and implementation of problem-based activities "daunting", which has been shown in other studies (De Beer & Petersen, 2016). The foldscope is also a new tool that teachers were not familiar with. They did not really know what to expect and they had to acquire a set of new skills.

Teacher 1 conducted the foldscope activity with two classes. The first lesson was challenging as the teacher realised that the instructions were difficult for the learners to follow. Therefore, the teacher reflected "how can I improve my next lesson?" The teacher found videos that showed step-by-step instructions for the learners to follow, thus the second lesson went much better. Learner 9 said that "the instructions on the paper in the package was very difficult to follow and was unclear, but the video was helpful".

Teacher 2 indicated that it takes a lot of time to perfect the technique, thus losing valuable teaching time. Again, time is a major factor in the Life Sciences classroom, and many teachers avoid doing practical activities because of this. Teacher 2 added that there is value to doing hands-on activities in the Life Sciences classroom in order to develop fine-motor skills because "children aren't accustomed to paper model building and struggles with instructions". Both teachers reflected that the CAR assisted them in becoming more critical and reflective practitioners.

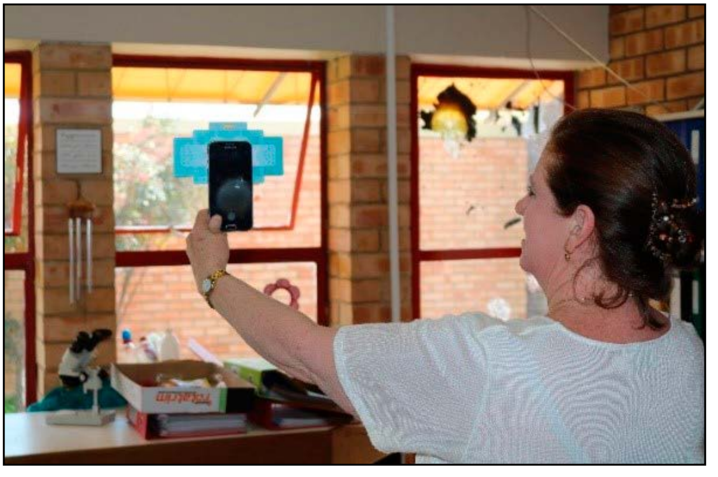

Figure 5: Life Sciences teacher using the foldscope during CAR

7.6. Looking at the data through a CHAT lens

CHAT is a useful lens to analyse data; to provide a "rich description". In Figure 2, focus is given to the Life Sciences classroom (where foldscopes were used), by identifying two interdependent activity systems (Mentz & De Beer, 2017). Although the teacher is teaching in a classroom setting, it does not necessarily mean that the learner is learning (Brown, 2003). The two activity systems in Figure 2 show the learner as *subject*, engaging in learning activities (diagram on the right); and the teacher as *subject* facilitating the foldscope learning activity (diagram on the left). The use of CHAT in this rather unconventional way (Mentz & De Beer, 2017) allowed the researcher to see what transfer of affective outcomes took place in the classroom using foldscopes. The CHAT analysis showed that the learners and the teachers obtained affective outcomes, which is surprising as often there are conflicts in terms of contradicting (non-aligned) *objects* in the two juxtaposed activity systems. In this case, there was good alignment between the objects in the two activity systems. The teachers appreciated the role of CAR in their own professional development; and the learners actively learnt Life Sciences concepts inside and outside the classroom. The teachers' design of the learning activity supported the realisation of affective outcomes by the learners.

8. CONCLUSION

Not only did teachers indicate that their engagement in CAR assisted them to become more critical reflective practitioners, but the learners also achieved valuable affective outcomes through their participation in the foldscope learning activity. Teachers that engaged in CAR found it very stimulating and exciting to create successful activities that contributed to learners' enjoyment of science. Teachers also improved their research skills, which should enhance teaching and learning in the Life Sciences classroom.

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