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INTEGRATING FOLDSCOPES INTO PROBLEM-BASED LEARNING

Abstract:

Skills required in the 21st century necessitate teaching methodologies that educators use to equip learners for practice. Problem-based learning (PBL) supports the development of 21st-century skills as it fosters critical thinking, problem solving, creativity and collaboration. The current research aimed to determine whether Life Sciences (Biology) methodology student teachers could integrate the use of foldscopes into PBL. The research found that student teachers experienced the foldscopes as exciting, and revealed positive responses for classroom use. Some student teachers were, however, unable to develop a PBL activity for their learners, and leaned towards traditional teaching methods. Cultural historical activity theory (CHAT) was used as lens to analyse the activity system and identify tensions within the system.

Keywords:

Cultural historical activity theory; Foldscopes; Self-directed learning; Problem-based learning; 21st-century skills

JEL Classification: I24, I29

Introduction

To survive in the 21st-century work environment it is envisaged that specialised skills will be required (Scott, 2015b). Wagner (2014) identified seven survival skills that learners need to function within the 21st century. Skills identified for the purpose of this research were critical thinking, problem solving, teamwork, creativity and flexibility skills. To foster the identified skills, teaching should develop reasoning and problem-solving abilities of learners, nurture originality and encourage collaboration and communication (Saavedra & Opfer, 2012). Different definitions for critical thinking have been put forward; however, for the purpose of this research, critical thinking is described as a process of divergent thinking whereby alternative options are explored (Vandsburger, Duncan-Daston, Akerson & Dillon, 2012). Critical thinking skills are closely related to problem-solving skills (Scott, 2015b). Problem solving can be described as ways to disentangle contradictory and conflicting information whilst emphasis is placed on the importance of teamwork in the problem-solving process (Scott, 2015b). Collaboration entails that members of a team contribute to the task at hand. This also entails that members must be willing to make concessions and settle for other ideas than their own to achieve a common goal. Problem solving also involves creativity, which Gardner (2010) describes as individuals who can think of new ideas in different and innovative ways to solve problems; therefore, divergent thinking is important. Lastly, flexibility can be defined as a characteristic that helps one to find original and adjustable solutions to a problem (Ionescu, 2012). Ionescu (2017) further emphasises that one needs to be inflexible at times, as a solution to a problem can best be found by using existing approaches whilst other instances lend the opportunity for a new approach towards problem solving to be considered.

Saavedra and Opfer (2012) argue that in the 21st century, teaching should move away from rote teaching and should focus on skills such as creativity, teamwork and thinking skills, and should utilise technology to develop learners' problem-solving and communication skills. Unfortunately, rote teaching and learning are still evident in South Africa (De Beer & Ramnarain, 2012) and in other countries (Wagner, 2014). An inflexible curriculum with stringent dates for the finalisation of specific topics may be a contributing factor to traditional teacher-centred methods (Harper, 2017). To address the 21st-century skills, Scott (2015a) calls for a change in learning content and teaching methods.

Problem statement

It is important to address the 21st-century skills with student teachers; therefore, the aim of this research was to establish whether Life Sciences (Biology) student teachers were able to develop a creative activity using problem-solving techniques. In order to develop this activity student teachers had to explore the integration of foldscopes into problem-based learning.

The research question that informed this research was, "What are the perceptions of student teachers using foldscopes in a Life Sciences classroom?" Furthermore, the research was also aimed at answering the question, "How can foldscopes be integrated into a problem-based learning (PBL) lesson?" To address these questions, student teachers were asked to develop a PBL learning activity for Life Sciences learners integrating foldscopes into this activity.

Conceptual framework

The identified concepts underpinning this research are described in more detail below.

Problem-based learning

Barrel (2010) is of the opinion that PBL is an ideal teaching methodology to develop 21st-century skills in learners. Scott (2015a) suggests that learning activities should be planned to establish a connection to real-world problems to foster learning. Barrows (1996) introduced PBL as a teaching methodology in the medicine field, and maintained that PBL is student-centred, that learning takes place in small groups, and that solving problems should be the motivation for learning. The teacher's role should change from that of a provider of knowledge to that of a facilitator, engaging the learners in thinking aimed at finding solutions. Through this methodology, learners would obtain information through self-directed learning (SDL), a process through which learners identify their own learning needs (Knowles, 1975). This implies that learners should be able to set their own learning goals and then identify learning resources to attain the goals set. Lastly, learners should be able to evaluate the outcomes of their own learning processes. Interdependence (each individual is concerned about the performance of all the other group members) is an underlying principle of PBL and enhances group effectiveness (Smith, Sheppard, Johnson & Johnson, 2005). Azer (2005) emphasises the importance of assigned roles of group members during PBL.

Through PBL, learners acquire content knowledge by applying creative problem-solving skills to solve real-world problems (Sutton & Knuth, 2017). Dolmans, De Grave, Wolfhagen-Cees and Van der Vleuten (2005) caution that problems should not be straightforward as learners should be challenged when solving the problem. Posing a problem should therefore be done in such a way that multiple solutions become possible through discussion (Hmelo-Silver, 2004) in order to stimulate debating and reasoning amongst group members. This is an important element in order for group members to come to an agreement ultimately to resolve a problem through discussion (Barron, 2002).

Choi, Lindquist and Song (2014) remind educators of the reality that the perceived results of PBL may be a time-consuming effort as critical thinking, which is an integral part of the process, may be a slow process to cultivate among learners. These challenges, which might occur when changing to a PBL approach, may be the reason why some educators were inclined to combine PBL with components of traditional learning methods, according to Lenkauskaitè and Mazeikienè (2012) who report that educators provide the problems to the learners and control the discussions during PBL. Dolmans et al. (2005) argue that over-controlling the PBL process defies the SDL approach.

Foldscopes

Foldscopes are described as origami-based paper microscopes (Cybulski, Clements & Prakash, 2014) and were developed at the Stanford University with the aim of providing low-cost microscopes, which can be used instead of using expensive scientific equipment (Marcus, 2017). The lens of a foldscope has the ability of a 2,000x magnification (Cybulski et al., 2014), which makes it the ideal microscope to use in a school laboratory (Kormann, 2015), as the foldscope is very small (5,8 cm x 15,24 cm) when folded (Marcus, 2017) and is easy to carry around (Ahuja, 2014). These microscopes have the added advantage that it can be attached (using magnets) to a smartphone (a mobile telephone with a built-in camera) to take pictures of the observed object (Kormann, 2015). It can be used outdoors as the foldscope must only be turned towards any light source to observe the image (Marcus, 2017). This makes it an ideal instrument to foster inquisitiveness in learners as they can explore the microscopic world, which they might not experience if they have to rely on expensive equipment only (Marcus, 2017). Ahuja (2014) reports that the inventor visualised that children around the world would have access to foldscopes to stimulate their interest. Teachers might be reluctant to allow learners to use foldscopes regularly because they might fear that the learners will damage them (Kormann, 2015), which will defeat the use of foldscopes at school level.

Theoretical framework

The third-generation cultural historical activity theory (CHAT) (Engeström, 1987) was used as theoretical lens for the analysis of data. The activity as unit of analysis was therefore used to identify and explore individual actions within the activity system (Hashim & Jones, 2007). CHAT has its roots in Vygotsky's theory of mediation (Veresov, 2009). A social environment functions as the framework for cognitive development, which first takes place on a social level before internalisation occurs (Veresov, 2010). Tools, which are culturally based, are used in the social activities between individuals (Stetsenko, 2010). The strength of using CHAT as an analytical unit is that the activity systems function as a single unit and therefore all the effects of the different components of the system are used for analysis (Foot, 2014).

CHAT is also an indication of tensions between the different elements of the activity. These elements can range from tensions evident in a single element of the activity system to tensions between activity systems (Engeström, 1987). Level 1 or primary tension occurs within a single node of the activity system, secondary tensions are evident between any two nodes or constituents of the activity system, whilst tertiary tensions occur when there is a contradiction between two activity systems. Level 4 or quaternary tension takes place between a central activity and adjacent activities (Engeström, 1987).

According to Engeström and Sannino (2010), these conflicts or tensions within the activity system are the driving forces for transformation within an activity system. Learning within the activity occurs when an initial idea is transformed into a complex object, which leads to a changed form of practice as well as the formation of theoretical concepts. These contradictions become the driving forces for expansive learning, especially if a new object is identified during this process. Engeström and Sannino (2010) expand on these driving forces and identify seven actions within this expansive learning cycle ranging from analysing the existing activity system to forming a new and stable form of practice through evaluation and reflection processes. The analysis aims to identify the contradictions within a system, which need to be resolved. By identifying new objects within the system, there is movement within the zone of proximal development (ZPD) a term, which Vygotsky (1978) described. Veresov (2009) elucidates that Vygotsky defined the ZPD as process of development and not the final stage of development, but the ZPD represents the learning space wherein an individual is located at a specific point of time. Roth and Lee (2007) state that two forms of learning are possible within the zone of proximal development. Within this ZPD, a less experienced individual can learn from a more knowledgeable peer, or learning can take place between peers at the same developmental level.

Engeström (2009) points out that the object of the activity system is important as it directs the activity system. The intention of the objects between two activity systems might differ, however, to which McNeil (2013) refers as the contradiction of control between the two systems.

In this research, CHAT was used at the interpersonal level as described by Mentz and De Beer (2017). This research focused on the teaching activities of the facilitator who fostered

PBL infusing foldscopes in a methodology course (activity system 1). Activity system 2 refers to the learning activities of the student teachers who had to use PBL as an approach to incorporate foldscopes into the activity that they had to develop.

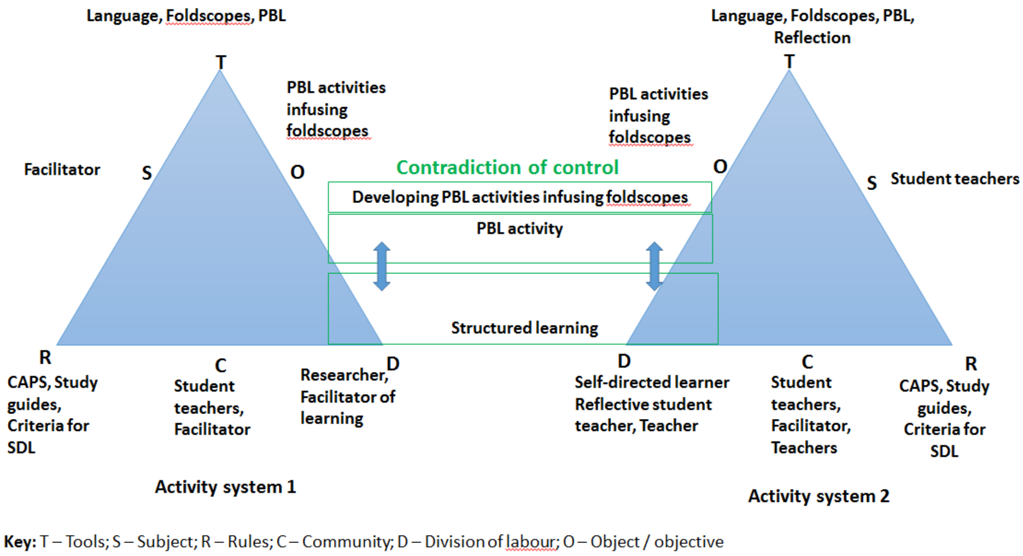


Figure 1. The different components of the activity system in this research

Source: Adapted from Engeström (1987)

In activity system 1, the focus is on the lecturer as facilitator who introduces PBL as teaching methodology in the classroom. PBL as a SDL method forms part of the outcomes of the study guides of the student teachers. PBL is a prerequisite for completion of their methodology course. The learning activity that student teachers had to develop for the current study had to be aligned with the Curriculum and Assessment Policy Statement (CAPS) (Department of Basic Education [DBE], 2011). The criteria for SDL, CAPS and study guides formed the rules of the activity system. The community consisted of the lecturer as facilitator and the student teachers in the methodology course. Tools of this activity system comprised language (which was used during discussions) and PBL as a teaching and learning strategy to foster SDL. Included in the tools was the use of foldscopes, which brought a practical dimension into the learning activity. The role division of the lecturer alternated between that of researcher and facilitator of learning.

In activity system 2, it was explored how student teachers (the subject) integrated foldscopes into the PBL activity (the object). Student teachers used language, foldscopes and PBL as teaching and learning method as mediating artefacts (tools). The lecturer, as facilitator, and student teachers in a Life Sciences methodology course formed part of the community of this activity system. As student teachers in their methodology course are also exposed to a practical teaching component, teachers who acted as mentors during this time also formed part of the community. The object refers to the PBL class activity that student teachers had to develop and which had to adhere to the CAPS syllabus (DBE, 2011) which all formed part of the rules of the activity system. 'Division of labour' refers to the division of roles of the student teachers, which alternated between that of a self-directed student teacher (in the university classroom) and that of a teacher whilst developing a PBL activity for their learners.

Methodology

This research was based on a qualitative design, and a purposeful sampling technique was used, which targeted fourth-year Life Sciences student teachers in a prescribed methodology course. Student teachers were asked to develop a PBL lesson activity integrating foldscopes into the lesson that had to incorporate practical work. Student teachers worked in groups of four (37 groups in total), and each group had a different theme (e.g. the cell and osmosis, plants, human anatomy) of the CAPS (DBE, 2011), which they addressed in developing their activity.

As an introduction, PBL as teaching strategy was revised with the student teachers who then assembled the foldscopes using the instruction sheet. In developing their PBL activity, student teachers also had to take a photo with their mobile phones of the image under the foldscope and include it as evidence with the activity.

The lecturer used PBL as a teaching strategy and therefore acted as facilitator in the classroom. The steps of the PBL approach summarised below and as described by Drăghicescua, Petrescua, Cristeab, Gorghiuc and Gorghiud (2014), were used during the lesson.

- Understanding the problem: Student teachers first had to identify information regarding the topics within their themes, which were suited to integrate the foldscopes into a PBL activity. They then discussed how they would pose a problem to their learners, and which activity would be suitable to incorporate the foldscopes.
- Curriculum exploring: Student teachers then had to plan ways in which they could develop an activity whose content was best suited, and how they would scaffold the activity for learners to implement PBL. Various activities had to be discussed, and student teachers then had to come up with a solution as to which content and which activity would be best suited for integrating the foldscopes.
- Problem solving: Student teachers had to present their solution in the form of a PBL activity for their learners. Student teachers then had to complete the activity themselves to explore whether the foldscope could successfully be incorporated into their activity.

Data was collected from pre- and post-questionnaires and artefacts (activities students developed) and photos (images observed under the foldscope). Reflective notes from the student teachers were also collected: firstly, showing how they had to reflect on how they had experienced the use of foldscopes, and secondly, how they experienced the use of the PBL method to develop their own activity. They also had to give feedback about how they would integrate foldscopes into a PBL lesson in their classroom. The artefacts (PBL activities that student teachers had to develop) were assessed to explore how they had used PBL to integrate foldscopes into a lesson activity.

Student teachers were informed that their lesson – integrating foldscopes into PBL – would be used for research purposes, and they completed informed consent forms, which stated the purpose of the research. Although the student teachers were under no obligation to complete the pre- and post-questionnaires or to provide the lecturer with digital images, which could be used for research purposes, PBL formed part of the outcomes of their curriculum and they had to complete the activity. Only data from student teachers who gave their voluntary consent to participate in the research were used in this research. An independent researcher collected the voluntary consent forms and made copies of the artefacts of those student teachers who were willing to participate in the research. Names of student teachers did not appear on the artefacts; therefore, student teachers who did not participate in the research were not disadvantaged.

Data obtained from the questionnaires, reflective notes from the student teachers and artefacts were transcribed and analysed assigning codes to similar concepts (Saldaña, 2013). Codes were then organised into categories and themes.

Findings and discussion

Primary, secondary and tertiary tensions were identified in this activity. Reflective notes from student teachers and the collected photos centred on the use of foldscopes whilst the questionnaires, reflective notes and the artefacts comprising activity provided feedback on PBL.

Foldscopes

Secondary tensions were identified between the subject and tools node. The majority of student teachers reported that the foldscopes were light in weight and exciting to use, especially outdoors. Positive tensions were therefore identified within this activity system. Student teachers enjoyed working with the foldscopes, as one of them indicated, "[f]oldscopes were exciting … I would use it in my class." Student teachers were also of the opinion that foldscopes would render a similar experience to learners than a microscope. "I learned a lot and will definitively use it because learners can still get the same learning experience of microscopic investigations." This research indicated that students were amazed that they could use foldscopes to take pictures of their own research. "I was stunned when we first saw a clear image on the mobile phone screen." Foldscopes have the added advantage that it can be attached to a smartphone (Kornmann, 2015).

Some student teachers stated that they experienced problems when focusing the object under the foldscope. One group reported:

> We had trouble focusing the images to get a clear image. In the end, with great patience, we were able to focus the image but moving it closer or further away from the slide until a clear image was observed.

Student teachers indicated that, although they initially experienced problems when focusing, perseverance was the key to use the foldscopes successfully. "Initially, we struggled to focus the lens, which led to blurred images. As we progressed, we became better at using the foldscopes and actually enjoyed the experiment."

Feedback from the student teachers also indicated that they found the microscope user-friendly and easy to handle due to the light weight of the microscope, which is consistent with the research of Ahuja (2014). They indicated, "[t]he microscope is easy to handle because it is small and light" and some student teachers were amazed to perceive the detail of the images, "[w]e saw detail of a pollen grain that could never be seen with the naked eye" due to the high magnification power of the foldscope (Cybulski et al., 2014). Student teachers realised the value of using the foldscopes outdoors as indicated, "[s]o we didn't need to transport plant samples to the laboratory, and could use the microscope where we wanted to."

Figure 2 illustrates some of the images captured by the student teachers with the foldscopes.

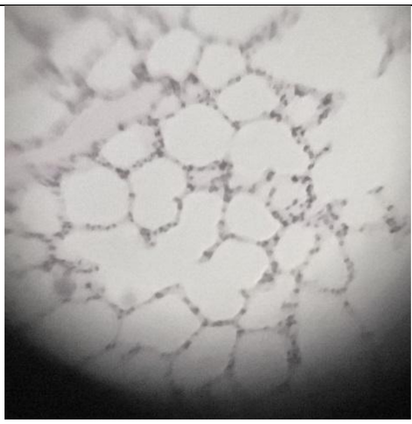
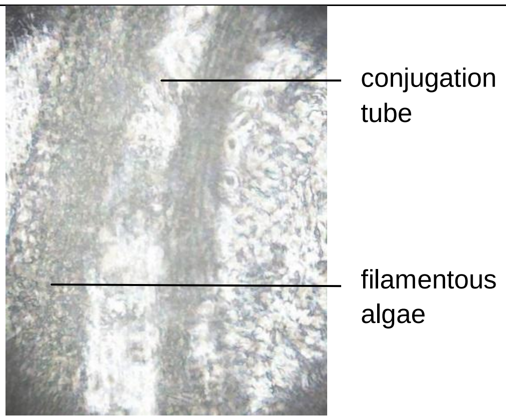
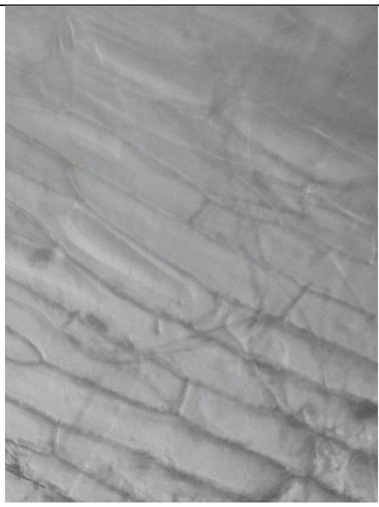
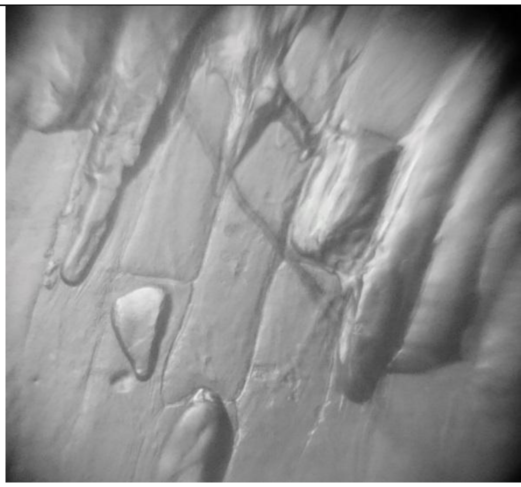
 Lung alveoli (prepared slide)	 Conjugation between two filamentous algae (own preparation)
 Onion epidermis before osmosis (own preparation)	 Onion epidermis after osmosis (own preparation)

Figure 2: Images observed under the foldscopes

Student teachers were of the opinion that foldscopes could expose learners to the use of a microscope, especially in under-resourced schools, “[t]he foldscope is a very good source for schools that are not fortunate enough to buy real microscopes and also give those learners a good and real experience with microscopes.”

Problem-based learning

Figure 3 illustrates the tensions that were evident in the activity system.

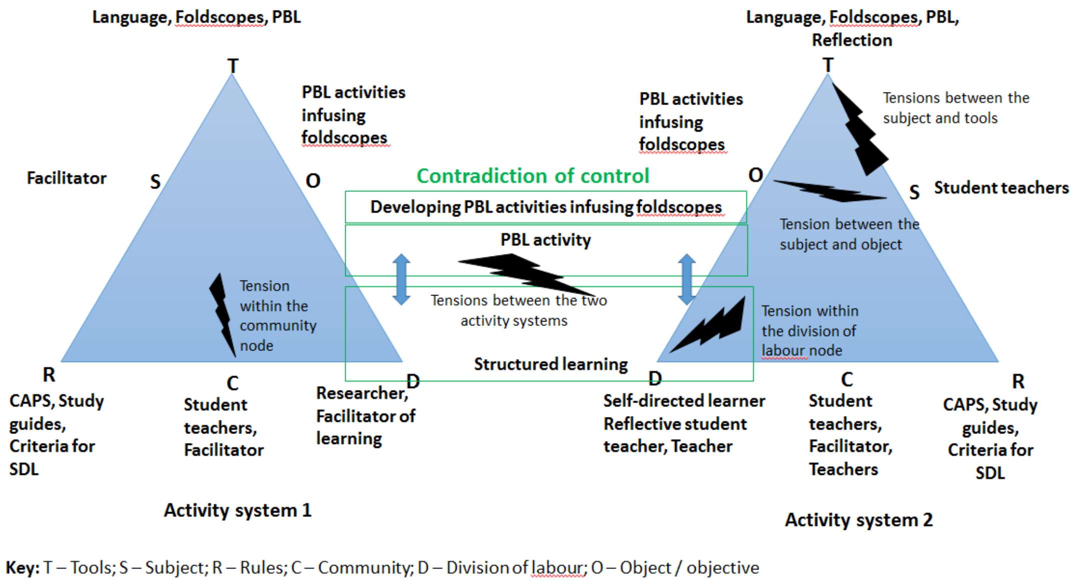


Figure 3: Tensions that manifested in the activity system in this research.

Primary tensions were evident in the community node. Some student teachers were able to create a problem that could be researched or which generated different solutions; yet, they experienced difficulties to come to an agreement to solve the problem and strongly relied on the facilitator to make the decision for them, which indicated tensions within the community. Some student teachers therefore were still unable to follow the steps in the problem-solving process of PBL. This was also highlighted in the research by Hassan (2013).

Secondary tensions were evident in the activity system between the subject and the object.

Student teachers were of the opinion that PBL improved critical thinking, “to make learners think critically and teach them how to implement and think about solutions”, which was consistent with the research by Scott (2015b).

Assessment of activities that student teachers compiled however revealed that most groups were unable to develop a lesson activity integrating foldscopes using the process of PBL. These student teachers were able to use PBL to set a problem, but then moved away from the PBL process and compiled assignments for their learners in the form of a question-and-answer activity. One example follows where a group decided to use PBL. They described a scenario for their learners to determine under which circumstances bread dough would rise. They then proceeded to ask learners to define a problem and to think of different solutions. Thereafter they switched to a more traditional approach by asking the learners to indicate the importance of respiration during the fermentation process, described the experiment that learners had to follow, and required from learners to make observations and come to a conclusion regarding the prescribed experiment. This is consistent with research by Lenkauskaitė and Mazeikienė (2012) where teachers infused PBL with traditional learning methods. This refers to the contradiction of control as described by McNiel (2013) where PBL activities are infused with structured learning, providing an indication of a tertiary tension. Reflecting on this process, student teachers were of the opinion that they would be able to implement PBL effectively but that they had to become more familiar with the process themselves, "[i]t is still difficult for me to implement the method correctly, I still want to give the learners too much information, but I now know what I'm doing wrong and can work on it."

A few groups were able to use the PBL method effectively to incorporate foldscopes into the lesson activity they had developed. In this example, the student teachers used a scaffolding exercise to support their learners to follow the process of PBL. They first set a scenario, which included a problem. Then they required the learners to follow the process of PBL with leading questions such as:

- Examine the problem
    - Collect necessary information, learn new ideas, principles and skills on this concept
- Do research on what is known to you
    - List the known information and indicate the extra information you need to obtain
    - Where can you find sources to investigate the problem as well as additional information?
- Define the problem
- Investigate possible solutions
    - List possible actions and solutions to the problem
- Choose a possible solution
    - Clearly indicate which solution was selected and supported with the relevant information, and give evidence why this solution was appropriate
- Evaluate your solution
    - How successful was your solution?
    - Is there a step you feel can be improved?

Primary tensions were also evident within the role division of the activity system. Students experienced difficulties in alternating their roles between that of a student teacher and that of a teacher. One group of student teachers decided to support the learners in their PBL activity by indicating the relevant apparatus they should use. Their own metacognitive thinking revealed that they realised that that this would restrict learners in coming up with possible solutions as they indicated, "[w]e thought to provide the necessary equipment for the investigation. The following also came to our awareness: What if the learner now thinks of another method to solve the problem for which the proposed apparatus is not appropriate?"

Primary tensions identified in the community node revealed that student teachers realised the importance of group work in solving problems as indicated:

> The whole class works together to try to solve a problem. If the one strategy doesn't work, you can move on to a next strategy. Using this method, learners will realise that you will not always get to the answer with your first attempt, you just have to keep on trying.

Scott (2015b) also indicated that teamwork is important in the problem-solving process.

Students were willing to incorporate foldscopes into PBL but they felt that more time would be needed to incorporate PBL into their lessons – "I think this foldscope went well with problem-based learning, but because no-one knew how it works … I will give more time so that learners have longer time to do this." Another group indicated, "[t]ime management is constantly and issue". This is consistent with research, which indicates that it is time-consuming to instil the PBL process into learners (Choi et al., 2014).

Conclusion

This research revealed that it is possible to integrate foldscopes into PBL. PBL will help student teachers to develop problem-solving skills, which are important 21st-century skills. Student teachers however still had the tendency to fall back on traditional teaching methods when they developed a learning activity. In future more time will therefore have to be spent with student teachers to familiarise them with the process of PBL before it is expected of them to develop their own PBL activities for a classroom setting. Infusing foldscopes into classroom teaching will enable more learners to experience the excitement of doing investigations. Although student teachers experienced the use of foldscopes as exciting, they indicated that they initially found it problematic to focus the foldscopes. More attention should therefore be given to skill development in using foldscopes before it is expected of student teachers to infuse foldscopes into an activity that they develop. The findings of this research cannot be generalised as the research was based on a small sample size. This research forms part of a research project and will be introduced to a larger group of teachers. This will be done through short learning programmes, which will target in-service teachers.

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