

PROBLEM-BASED AND SELF-DIRECTED LEARNING OUTCOMES DURING AN INDIGENOUS KNOWLEDGE INTERVENTION FOR LIFE SCIENCES TEACHERS

Lizanne de Villiers

North-West University
South Africa

22783652nwu@gmail.com

Josef de Beer

North-West University
South Africa

Josef.debeer@nwu.ac.za

Aubrey Golightly

North-West University
South Africa

Aubrey.golightly@nwu.ac.za

ABSTRACT– Teachers often lack appropriate pedagogical content knowledge to infuse indigenous knowledge in Life Sciences classrooms. This paper focuses on Life Sciences teachers’ skills when infusing indigenous knowledge by using problem-based learning after these teachers have attended an indigenous knowledge short course. Learners enter the Life Sciences classroom with indigenous knowledge, and a cultural border crossing is essential to limit discrepancies between their home and school realities. Problem-based learning lends itself to the infusion of indigenous knowledge with classroom activities based on the tenets of the nature of science. As a theoretical framework, we made use of embodied, situated, distributed cognition. Participating Life Science teachers were chosen randomly from teachers who voluntarily attended one short course (one cohort in Limpopo and one in the North West province). The quantitative data reported on in this paper capture the feedback of all 75 participants who took part in this study. From these 75 teachers, 40 were randomly selected to complete the questionnaire, and another eight (8) were selected for individual interviews. A qualitative case study research design with elements of phenomenology was used and data were collected by making use of questionnaires and interviews with teachers. The data were analyzed thematically. Third generation Cultural-Historical Activity Theory was used as the research lens. The results of the research showed that teachers have limited pedagogical content knowledge regarding both indigenous knowledge and problem-based learning and the intervention seemed to have succeeded in changing their pedagogical content knowledge as well as their attitudes in these regards. Most of the teachers (95.1%) who completed the questionnaires indicated that the short course changed their view on the value of the use of problem-based learning in classrooms. The main tensions the teachers reported that could hinder the use of problem-based learning and the infusion of indigenous knowledge into Life Sciences contents, were not enough teaching time and a lack of necessary teaching and learning resources.

Keywords: Problem-based Learning (PBL); Indigenous Knowledge (IK); Self-directed Learning (SDL); Pedagogical Content Knowledge (PCK); Embodied, Situated, and Distributed Cognition (ESDC); Cultural border crossing.

1. INTRODUCTION AND PROBLEM STATEMENT

The historic events of 1994 that brought about democracy in South Africa, led also to the reform of educational policies, contents and methods (Khupe, 2014). Even though educational policy documents require the integration of IK with the contents of the curriculum, various factors hamper this integration. Teachers tend to shy away from integrating IK in their classrooms due to lack of knowledge thereof – leading to a marginalization of the rich knowledge contained in IK systems (Cronje, 2015). De Beer (2015) argues that the intellectual heritage of non-Western people is often viewed as inferior by the European academic elite. Currently, a great amount of attention is given to this issue in South Africa with arguments for Afrocentric approaches (as opposed to Eurocentric approaches) and decolonization of the curriculum. IK seems to provide an excellent approach into the often abstract and symbolic Western science taught in schools and is an appropriate angle of incident for approaching the national curriculum of South Africa. Unfortunately, Western knowledge is often seen as “true science” and IK is marginalized and labelled as unscientific or as a pseudoscience (De Beer, 2015). In light of this

background, this study made use of an intervention (a three-day short course) in an attempt to empower Life Sciences teachers to use PBL which may promote SDL when teaching IK.

Teaching and learning in Life Sciences classrooms should rather be based on constructivist approaches as opposed to the behavioristic approaches which are still prominent in Life Sciences classrooms in South Africa (Botha, 2012; Petersen & De Beer, 2012). With the current information revolution, it is necessary to implement learner-centered instruction to foster learners' self-directed learning. PBL as a pedagogical strategy, leads to knowledge construction, the development of various skills (such as problem-solving, critical thinking and collaborative learning), as well as challenging learners to take responsibility for their own learning (Ribeiro, 2011). PBL is, however, rarely used in Life Sciences classrooms. A possible reason for this is a lack in the necessary PCK for the successful implementation of PBL. This is an unfortunate situation as the essence of Life Sciences (with reference to the tenets of the nature of science) lends itself eminently to PBL.

The essence of this study lies, therefore, in the need to equip Life Sciences teachers with the PCK (as proposed by Shulman, 1986) needed to integrate IK in Life Sciences classrooms by using PBL. Thus, the purpose of this research study was to determine how the use of PBL during an IK intervention can empower Life Sciences teachers to manage SDL processes in their classrooms.

2. CONCEPTUAL THEORETICAL FRAMEWORK

As the theoretical framework for this research, we made use of Embodied, Situated and Distributed Cognition (ESDC) (Hardy-Vallee & Payette, 2008). These authors view cognition as a holistic process rather than the traditional view of the brain as the only place where cognition takes place. The first aspect of this theory is that cognition is embodied. As the brain is embedded in the body, cognition cannot be separated from action and perception. This implies that the experiences of learners and their feelings towards the content that is learnt, plays a role in cognition. The teaching-learning approach in classrooms as well as the content influences learners' perceptions of their learning, where content based on cultural knowledge in learner-centered classrooms may make for positive perceptions. Secondly, cognition is situated – thus influenced by learners' prior knowledge, background and environment. IK (prior knowledge) is, therefore, an important part of cognition. Lastly, social interactions are part of cognition – thus, cognition is distributed. IK is collectively held by members of the community – therefore, distributed. Using problem-based learning – a social constructivist pedagogical strategy – will contribute to distributed cognition as teaching-learning takes place in an environment with positive social interactions. This was an ideal theoretical framework for this research as it effectively supported the aims of the study.

IK is fluid knowledge, skills and attitudes particular to a specific indigenous group of people. It is developed over centuries and continues to develop by interactions of people with nature. It is conveyed (usually verbally) from generation to generation. This knowledge, skills and attitudes are cultural and is mainly used for survival and to enhance the quality of the people belonging to a specific group of people (Le Grange, 2004; Naidoo, 2010; Mothwa, 2011; Zinyeka, 2013; Khupe, 2014).

Jegede and Aikenhead (1999) argue that learners often experience the world they live in and school science as two different cultures (or what Vygotsky, 1975, refers to as spontaneous and scientific concepts) and, therefore, teachers have to ensure that these two cultures exist in harmony in order to ease the crossing of cultural borders. If the cultures of school science and the learners' living world are not aligned, learners will be alienated from one of these cultures. This will result in marginalization and a reconstruction of their living world or alienation from school science (Jegede & Aikenhead, 1999). Life Sciences teachers need, therefore, to make use of appropriate pedagogical strategies to act as cultural brokers who can facilitate the crossing of borders between the living world and the culture of school

science. This may be done by infusing IK into the contents of the Life Sciences curriculum by making use of PBL as an example of a social-constructivist pedagogical strategy.

PBL is learner-centered, where an authentic, ill-structured, open-ended problem is used as a learning stimulus. Learners work collaboratively to find solutions to real-world problems. Learners are responsible for directing and constructing their own learning and teachers plan and facilitate the learning process (Barrows, 1986; Pawson, Fournier, Haigh, Muniz, Trafford & Vajoczki, 2006; Veldman, De Wet, Ike Mokhele & Bouwer, 2008; Ribeiro, 2011; Ishak, Omar & Sum, 2015). For the purpose of this research we focused on a hybrid PBL, which entail direct teaching strategies such as lectures and demonstrations being used in the PBL process (Golightly & Raath, 2015).

In the literature PBL is highlighted as a pedagogical strategy which promotes learners' self-directedness in learning (Lee, Mann & Frank, 2010; Czabanowska, Moust, Meijer, Schröder-Bäck & Robertsen, 2012; Malan, Ndlovu, & Engelbrecht, 2014). It can be assumed that the implementation of PBL in Life Sciences classrooms will have a positive effect on the self-directedness of learners. Knowles (1975) defines SDL as a process during which individuals identify and formulate their own learning needs and learning goals, they identify their own learning resources, they make decisions about and implement appropriate learning strategies and evaluate the outcomes of their learning. This may be done with or without support from others. De Beer & Mentz (in press) showed that the holders of IK are per definition self-directed problem-solvers as their indigenous practices were developed (over time) in response to certain real-life, survival-related problems.

3. METHODS

3.1. Approach and paradigm

This paper only reflects on the qualitative component of a broader mixed-methods study. A qualitative case study research design with intertwined elements of phenomenology was used for this research. The phenomenological character stemmed from the attempt to capture the lived experiences of teachers on the incorporation of IK and PBL in their classrooms. Each participating teacher was studied while the beliefs of these teachers with regard to their professional development served to provide a deeper understanding thereof.

The research paradigm used for this study was interpretivism, thus we sought to understand specific phenomena by studying the meaning that people assign to these phenomena. From this point of view, an understanding of teachers' perceived PCK of PBL and IK was constructed and factors that promoted and hindered the use of PBL and the integration of IK were identified.

3.2. The intervention

The data for this study were collected during two three-day IK interventions for Life Sciences teachers. The first intervention took place at the Turfloop campus of the University of Limpopo in Polokwane in the Limpopo province on 27-29 June, 2016, and the second one at the NWU in Potchefstroom in the North West province, on 18-20 July, 2016. These interventions formed part of a project, "The affordances of indigenous knowledge for self-directed learning". This study reports on one aspect of the project, namely the implementation of PBL as a pedagogical strategy in the IK intervention.

During these interventions, teachers were introduced to ways in which IK can be incorporated in their Life Sciences classroom by making use of the processes of science. These interventions consisted of, amongst others, laboratory experiments, such as anti-microbial tests on medicinal plants, through PBL activities. There was a strong emphasis on providing teachers with a more nuanced understanding of

the nature of science, the nature of IK and the principles underpinning SDL (including the link between PBL and SDL).

3.3. Cultural-Historical Activity Theory (CHAT) as the research lens

Engeström (2001) argues that individuals cannot be fully understood without considering the influence of culture (based on the theory of Vygotsky, 1978). By making use of a third generation CHAT as the research lens, a Nieu-Vygotskian perspective on learning and the influence that symbols, artefacts, cultural practices, rules and different stakeholders have on cognition was provided. This research views the influences of different aspects of the activity system on the object, which is the development of teachers' PCK to teach IK by using PBL. These aspects include the subject (Life Sciences teachers), tools (PBL, IK and resources), rules (the principles of PBL, the rules of the CAPS document, the tenets of the nature of science, the tenets of the nature of indigenous knowledge and classroom atmosphere), the community (The Department of Education, learners and the short course facilitators) and the division of labour (the teacher as a facilitator, a self-directed learner, an agent of change and a critical reflective practitioner).

The CHAT lens was used to identify the tensions in the activity system of participating teachers' classrooms with regard to the integration of IK in teaching and the use of PBL as a pedagogical strategy.

3.4. Data collection

Data were gathered by making use of questionnaires and semi-structured interviews. Two types of questionnaires were used to collect data. The first questionnaire, a self-constructed and open-ended questionnaire, was designed to test the teachers' views on and knowledge of PBL before and after the interventions (the items were developed based on an intensive literature study, and were scrutinized by subject specialists as well as research specialists). The second, a generic questionnaire, was completed by teachers after the interventions and was aimed at determining the thoughts of the teachers on different elements of the interventions. The semi-structured interviews were directed towards gathering data on the views of teachers on the changes brought about in their skills and attitudes as a result of the interventions as well as the factors that promote and prevent the use of PBL and the integration of IK.

3.5. Sampling

A convenience sampling method was used, implying that only Life Sciences teachers who attended the interventions (short courses) participated in this study. All the teachers who attended the courses (n=62 in the Limpopo province, and n=13 in the North West province) were given the opportunity to complete the generic questionnaire after completing the short course. Forty randomly selected teachers were asked to complete the open-ended questionnaire before and after the short course. Semi-structured interviews were conducted with eight randomly selected teachers who were willing to participate during the course of the interventions.

3.6. Data analysis

The data were analyzed by using a thematic data analysis and inductive (data-driven) coding was used. Data from the different instruments were coded according to the coding system of Saldana (2009). The first step in this process was reading through the data from the different instruments in order to obtain a broad view of the data gathered. Thereafter the data were coded – codes were identified as we worked through the data and after the coding process the codes were grouped into categories, which were grouped again to form themes. Seven themes emerged from the data.

3.7. Validity and trustworthiness

Construct validity (ensuring that the questionnaire measure what it is intended to measure) was ensured by asking a panel of experts (seasoned researchers, as well as the university's Statistical Consultation Services) to peruse the questionnaire and interview protocol. Triangulation of data helped to ensure trustworthiness in this research (Nieuwenhuis, 2010).

3.8. Ethical clearance

Ethical clearance was obtained for this study, and teachers voluntarily participated in the study. Teachers were informed that they could withdraw from the research at any stage.

4. FINDINGS AND DISCUSSION

The following seven themes emerged from the data:

4.1. Teachers' knowledge of and PCK regarding IK is limited

Participating teachers reported that their knowledge about IK as well as knowledge about ways to incorporate IK into Life Sciences lessons was limited prior to the interventions. One of the teachers reported: *"I didn't have this knowledge on indigenous knowledge. I didn't even think about it."* Another teacher commented the following: *"I just stick to the curriculum. I just teach theory from text books."* When asked about one of the teacher's views on the value of infusing IK in teaching, the following was reported: *"Although I see the value of IK, I do not know how to bring it alive in my classroom."* Certain misconceptions about IK, also contributed to the teachers' tendency to shy away from teaching IK in their classrooms. A teacher commented: *"At the beginning I had a misconception that indigenous knowledge means witchcraft and muthi."*

During this research study we found that many Life Sciences teachers have limited knowledge about IK and the ways in which to incorporate IK into Life Sciences lessons prior to the interventions. This finding is consistent with the findings of Cronje (2015), who showed that many Life Sciences teachers are not competent in facilitating meaningful practical work in IK. This may, amongst other reasons, be due to a lack in training offered by the Department of Education in this regard (Mothwa, 2011).

4.2. The PCK of teachers with regard to PBL is very limited

Only a small number of the teachers reported that they know about or use PBL prior to the interventions. The teachers who reported knowing about PBL, indicated that they did not know how to use it and refrained from doing so due to a lack of confidence in their skills to manage PBL classroom activities.

The teachers reported the following:

"I do not know what problem-based learning is."

"I read about it before, but I was not fully engaged with it."

"This is normally only used in the mathematics classroom."

"It's better to explain the work to learners, I don't like doing things in class where learners just do what they want."

From the data gathered before the interventions, it was clear that only a few of the participating teachers are knowledgeable about PBL – most of the teachers indicated that they have never even heard about it. The number of teachers who reported on using PBL, was even less due to their low PCK with regard to PBL. These findings concur with a study conducted by So and Kim (2009), that indicated that, although some pre-service teachers (who were the participants in that study) had a basic idea about PBL, their PCK about this strategy was insufficient, as they were not able to manage learning

experiences true to the nature of PBL. Veldman et al. (2008) found that some of the reasons for teachers not using PBL included incapability, lack of self-confidence, poor teacher training and defective skills to design PBL learning activities.

4.3. The teachers reported limited resources as one of the main reasons for using transmission-mode teaching

The participating teachers commented that, because of a lack in resources, they make use of transmission-mode teaching (chalk-and-talk). They reported using a theoretical approach to teaching – only teaching the contents of text books as they do not know other ways of teaching content without the use of laboratory equipment and academic material.

Some of the comments made by the teachers with regard to resources, are as follows:

“In most cases we do theory, we have poor resources.”

“The examiners used anti-microbial testing in question papers. This was in the question paper and we didn’t do it practically because of lack of resources - we just did it theoretically.”

“My school is under-resourced, so that’s why this programme is helpful.”

The results of this research highlighted that limited resources for teaching and learning may force teachers to use transmission-mode teaching (chalk-and-talk) where only prescribed content from the CAPS document is taught (ignoring IK). In this regard Hattingh, Aldous and Rogan (2013) are of the opinion that the completion of practical work is not significantly dependent on the availability of resources and that teachers who are motivated to do practical work, do so irrespective of poor teaching and learning resources. Thus, we can deduce that the notion of transmission-mode teaching including little practical work and no IK due to a lack of resources point to low levels of self-directedness as teachers do not set learning goals and plan their own learning activities in order to overcome this obstacle.

4.4. The short course seems to have succeeded in changing the PCK of teachers with regard to PBL

The quantitative data (which is not reflected upon in this paper) indicated that 59 of the 62 teachers (95.1%) who completed the questionnaire reported on having a more nuanced understanding of the value of PBL approaches in the classroom after completion of the course. More of the teachers have shown an informed view on PBL and the process thereof after the interventions than before the short course took place. A higher tendency to use PBL when designing lessons was shown after the interventions (in the post-intervention questionnaire) than before (in the pre-intervention questionnaire).

One of the teachers commented: *“I have learned that problems from learners’ environments will enhance learning”*. Another reported: *“Problem-based learning makes the learners think and work instead of the old method of teaching of just writing on the board. I want to use it”*. An example of how PBL may be used in a Life Sciences classroom provided by one of the teachers is as follows: *“Give them a problem, for example global warming, and expect them to come up with a solution based on the given problem.”*

The IK interventions seem to have had a significant effect on the PCK of the participating teachers as more of the teachers showed knowledge of and a tendency to use PBL when developing lesson plans afterwards. Therefore, this research concurs with the findings of Veldman et al. (2008) that reported

that the attitude of teachers towards skills used in implementing PBL is greatly influenced when they attend training programmes.

4.5. The short course seems to have led to the development of PCK on IK

The teachers indicated a more nuanced understanding of IK and showed the ability to develop lessons which included IK based on the pedagogical strategies dealt with during the course of the interventions. This became very clear from the Views on the Nature of Indigenous Knowledge questionnaire, which was administered as a pre- and post-intervention test. The data from this questionnaire was not reported on as it is seen as being beyond the scope of this paper.

One of the teachers commented the following on their knowledge about IK: *“This experience is wonderful because you come across more knowledge than when you were just reading from the text books.”* When asked whether one of the teachers will incorporate IK into their teaching, the following was reported: *“Definitely. I’ve learned how to use the things that I have to teach learners about indigenous knowledge so now I can feel confident and do it.”* One of the teachers reported on an aspect of IK they would use in a Life Sciences classroom: *“The fermentation process, making beer and the preservation of food, those methods can be linked to the curriculum.”* The following idea was reported by one of the teachers for a lesson including IK: *“An activity can be designed where learners do research on how elders would heal infections.”*

It was found that most of the teachers’ knowledge of IK and their strategies for teaching it in Life Sciences classrooms were influenced by the intervention. The teachers reported that they gained new knowledge on IK and learned new pedagogical strategies which can be used to teach IK in their classrooms. These findings correlate with the findings of an IK intervention programme for sciences teachers conducted by Cronje (2015) where the results pointed to a more informed view on IK and an increase in the PCK needed to include IK in the teaching of scientific contents. IK interventions seem to provide an answer to the teacher-training dilemma that seems to be experienced in South Africa.

4.6. The short course appears to have influenced the teachers’ attitude towards IK and PBL

The participating teachers showed a change in attitude with regard to both the use of PBL as a pedagogical strategy and the infusion of IK into the contents of the Curriculum and Assessment Policy Statement (CAPS) document. After attending the interventions, a number of the teachers indicated that they believe that using PBL as a pedagogical strategy is meaningful as it contributes to the development of critical thinking, problem-solving skills as well as acquiring skills, SDL and critical thinking. Their attitude towards IK and the teaching thereof as part of the content of the Life Sciences curriculum also seemed to have changed after the interventions.

One of the participating teachers commented the following with regard to the use of PBL as a pedagogical strategy after the interventions: *“It is important because it helps learners’ thinking processes.”* Another teacher mentioned that PBL is *“motivating as learners work towards answering a question.”* With regard to teaching IK in a Life Sciences classroom, one of the teachers commented: *“I had a lot of misconceptions, but I will teach it now because I know more about it and the learners can ask me questions and I can answer them.”* When the teachers were asked about their attitude about IK in teaching, the following was reported: *“It has changed, now I’m more open-minded.”*

A change in the participating teachers’ attitudes with regard to both the use of PBL and the infusion of IK into teaching was shown after the intervention. A study by Haney and McArthur (2002) pointed out a number of factors influencing the attitudes of teachers towards new notions in teaching. Doing things

in a certain way for years, may lead to resistance when new ways of doing things are introduced. Several changes have occurred in the South African curriculum since 1994 and teachers may have a negative attitude towards adapting to these changes. Training opportunities provided by the Department of Education are scarce (as mentioned earlier) and may play a role in the ongoing negative attitudes of teachers towards IK and social constructivist pedagogical strategies such as PBL. This intervention seems to have been successful in changing the attitudes of participating teachers in the use of PBL as a pedagogical strategy and the infusion of IK into their teaching.

4.7 The teachers’ perceived ability with regard to the management of activities promoting SDL seems to have improved as a result of the intervention

A number of the teachers reported that they consider their own ability to manage activities promoting SDL in their Life Sciences classrooms to have improved. They commented on realizing the importance of the role of IK and pedagogical strategies such as PBL on promoting the SDL of learners and consider themselves to be increasingly able to manage classroom activities that promote SDL.

Some of the comments in this regard are:

“I want to use problem-based learning in order to let learners learn to do things for themselves and be responsible.”

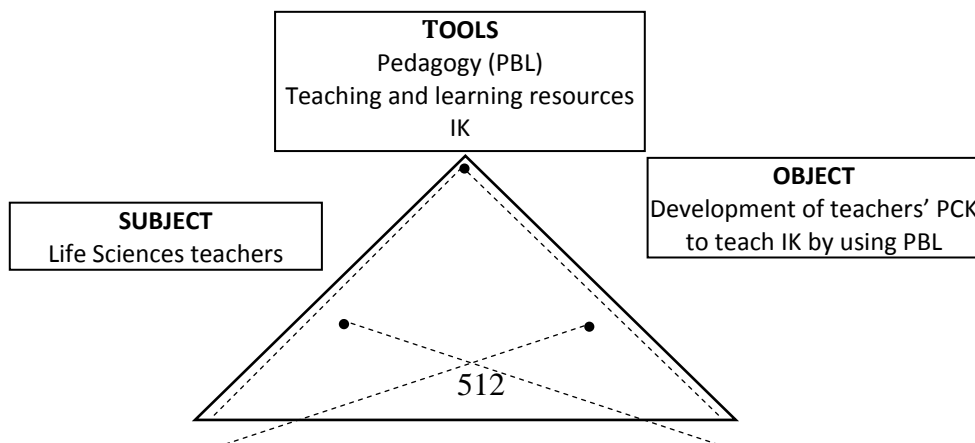
“I know now the importance of helping learners to become responsible for learning and stepping back to also learn from them.”

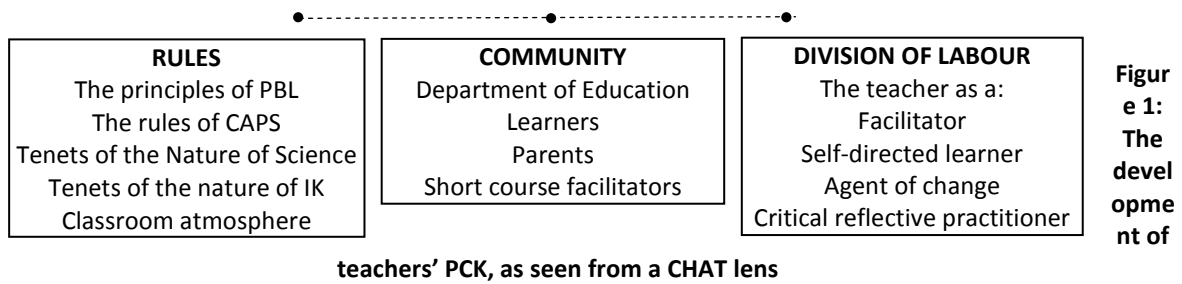
“I will use problem-based learning as it gives learners independence and it is more fun when you learn something on your own.”

Most of the teachers reported on understanding the link between PBL and SDL believing that they will now be able to manage SDL activities in their classroom. These findings are supported in other studies regarding the implementation of PBL to foster SDL (Lee et al., 2010; Czabanowska et al., 2012; Malan et al., 2014).

5. THE TENSIONS HINDERING THE USE OF PBL AS A PEDAGOGICAL STRATEGY AS WELL AS THE INFUSION OF IK IN LIFE SCIENCES BY USING CHAT AS A LENS

A CHAT lens was used to identify the tensions that occurred in the activity system of the participating teachers with regard to the use of PBL and the incorporation of IK into the teaching of Life Sciences contents. The tensions identified are discussed below.





The first tension that was identified exists because of the fact that IK is not formally recorded – the teaching thereof is hindered. Teachers normally shy away from teaching IK because of learners', parents' and other stakeholders' misconceptions that lead to an opposition of accepting IK as part of the curriculum – the second tension. Another tension is a lack in teaching-learning resources which hinders the teaching of IK. The CAPS document urges the integration of IK into the curriculum, yet little guidelines exist to assist teachers in this task – leading to tension. Life Sciences teachers' attitudes towards IK and PBL and their willingness to develop their PCK represents a further tension. Teachers also fear that learners might ask questions regarding IK which they will not be able to answer due to a lack of knowledge. Teachers' reluctance towards reflecting on their own teaching and learning methods also creates a tension in the activity system. Not enough teaching time and a very comprehensive CAPS document contribute to additional tension in the activity system of teachers. Teachers also seem to lack knowledge (PCK) regarding the principles and appropriate implementation of PBL in their classrooms. Lastly, a lack in self-directedness displayed by many teachers lead to teaching and learning practices staying the same instead of teachers acting as innovators and agents of change who adapt to the changing learning needs in South Africa.

A positive tension exists between the facilitators of the short course and the object, as interventions seem to have a positive effect on the development of the PCK of teachers. Teachers' role as agents of change – coupled with increased PCK and positive attitudes towards PBL and IK as a result of interventions – will positively influence the object. Thus, it may be deduced that despite the negative tensions mentioned above, interventions contribute to creating a number of positive opportunities in the activity system.

6. CONCLUSION AND RECOMMENDATIONS

The purpose of this research was to determine how the use of PBL during IK interventions empowers Life Sciences teachers to manage self-directed learning processes in their classrooms. Teachers who participated have limited PCK with regard to PBL and IK, and the interventions seem to have contributed towards the development of their PCK. Teachers' attitudes towards the incorporation of IK into their teaching and the use of PBL seem to have changed as a result of the intervention. A lack of teaching and learning resources is the most prominent tension, which may hinder the incorporation of IK into teaching and the use of PBL. Despite the tensions identified, the majority of teachers consider themselves more proficient in the incorporation of IK into their teaching by making use of PBL and managing classroom activities which will promote SDL. Based on these findings, it seems that the IK interventions succeeded in developing the PCK of teachers.

Communicating the findings of this study to the Department of Education may raise awareness of the positive influence of such interventions on the PCK of teachers. Teacher agency in terms of improvising shoestring-approaches in Life Sciences classrooms (to address the problem of under-resourced classrooms) seems to be a limiting factor in Life Sciences education. It is therefore suggested that

teacher agency and shoestring-approaches (improvising cheap alternatives) are emphasized in both pre-service and in-service education programmes. Findings from this study and similar studies may inform the Department of Education and other stakeholders (such as universities) of the importance of investing in the professional development of teachers.

ACKNOWLEDGEMENT

We would like to acknowledge financial support from both the National Research Foundation and the Fuchs Foundation.

7. REFERENCES

- Barrows, H. S. (1986). Problem-based learning in medicine and beyond. In L. Wilkerson & W.H. Gijselaars (Eds.), *New directions for teaching and learning. Bringing problem-based learning to higher education: Theory and practice* (pp. 3–13). San Francisco: Jossey-Bass.
- Botha, M. L. (2012). Lewenswetenskappe-onderwys in die een-en-twintigste eeu: 'n Paradigmaskuif: Oorspronklike navorsing. *Suid-Afrikaanse Tydskrif vir Natuurwetenskap en Tegnologie*, 31(1), 1–7.
- Cronje, A. (2015). *Epistemological border-crossing between western science and indigenous knowledge and its implications for teacher professional development* (Unpublished doctoral thesis). University of Johannesburg, Johannesburg.
- Czabanowska, K., Moust, J. H., Meijer, A. W., Schröder-Bäck, P., & Robertsen, H. (2012). Problem-based learning revisited: Introduction of active and self-directed learning to reduce fatigue among students. *Journal of University Teaching & Learning Practice*, 9(1), 6–19.
- De Beer, J. J. J. (2015). Die insluiting van inheemse kennis in die wetenskapklaskamer: 'n Betoog vanuit die kultuurhistoriese aktiwiteitsteorie. *Suid-Afrikaanse Tydskrif vir Natuurwetenskap en Tegnologie*, 34(1), 1–6.
- De Beer, J. J. J., & Mentz, E. (in press). 'n Kultuurhistoriese aktiwiteitsteoretiese blik op die houers van inheemse kennis as selfgerigte leerders: Lesse vir onderwys in Suid-Afrikaanse skole.
- Engeström, Y. (2001). Expansive learning at work: Toward an activity theoretical reconceptualization. *Journal of Education and Work*, 14(1), 134–156.
- Golightly, A., & Raath, S. (2015). Problem-based learning to foster deep learning in preservice geography teacher education. *Journal of Geography*, 114(2), 58–68.
- Haney, J. J., & McArthur, J. (2002). Four case studies of prospective science teachers' beliefs concerning constructivist teaching practices. *Science Education*, 86(6), 783–802.
- Hardy-Vallee, B., & Payette, N. (2008). *Beyond the brain: Embodied, situated and distributed cognition*. Newcastle: Cambridge Scholars Publishing.
- Hattingh, A., Aldous, C., & Rogan, J. (2013). Some factors influencing the quality of practical work in science classrooms. *African Journal of Research in Mathematics, Science and Technology Education*, 11(1), 75–90.
- Ishak, S., Omar, A. R. C. O., & Sum, S. M. (2015). Implementation of problem-based learning: A review on the challenges. *International Journal of Education and Research*, 3(8), 381–394.
- Jegede, O. J., & Aikenhead, G. S. (1999). Transcending cultural borders: Implications for science teaching. *Research in Science & Technological Education*, 17(1), 45–66.
- Khupe, C. (2014). *Indigenous knowledge and school science: Possibilities for integration* (Unpublished doctoral thesis). University of Witwatersrand, Johannesburg.
- Knowles, M. S. (1975). *Self-directed learning*. New York: Association Press.
- Le Grange, L. (2004). Western science and indigenous knowledge: Competing perspectives or complementary frameworks? *SAJHE*, 18(3), 82–91.
- Lee, Y. M., Mann, K. V., & Frank, B. W. (2010). What drives students' self-directed learning in a hybrid PBL curriculum. *Advances in Health Sciences Education*, 15(3), 425–437.
- Malan, S. B., Ndlovu, M., & Engelbrecht, P. (2014). Introducing problem-based learning (PBL) into a foundation programme to develop self-directed learning skills. *South African Journal of Education*, 34(1), 1–16.
- Mothwa, M. M. (2011). *Teachers' experiences of incorporating indigenous knowledge in the Life Sciences classroom* (Unpublished Master's thesis). University of Johannesburg, Johannesburg.
- Naidoo, P. D. (2010). *Teachers' interpretation and implementation of the policy on indigenous knowledge in the science national curriculum statement* (Unpublished doctoral thesis). University of KwaZulu-Natal, Durban.

- Nieuwenhuis, J. (2010). Qualitative research designs and data gathering techniques. In: K. Maree (Ed). First steps in research (6th Edition). Pretoria: Van Schaik, 69 -99.
- Pawson, E., Fournier, E., Haigh, M., Muniz, O., Trafford, J., & Vajoczki, S. (2006). Problem-based learning in geography: Towards a critical assessment of its purposes, benefits and risks. *Journal of Geography in Higher Education*, 30(1), 103–106.
- Petersen, N. T., & De Beer, J. J. J. (2012). Die professionele ontwikkeling van Lewenswetenskappe-onderwysers op basis van 'n ekologie van praktyk. *Suid-Afrikaanse Tydskrif vir Natuurwetenskap en Tegnologie*, 31(1), 1–11.
- Ribeiro, L. R. C. (2011). The pros and cons of PBL from the teacher's standpoint. *Journal of University Teaching & Learning Practice*, 8(1), 1–17.
- Saldana, J. (2009). *The coding manual for qualitative researchers*. London: Sage Publications.
- Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, 15(2), 4–14.
- So, H. J., & Kim, B. (2009). Learning about problem-based learning: Student teachers integrating technology, pedagogy and content knowledge. *Australasian Journal of Educational Technology*, 25(1), 101–116.
- Veldman, F. J., De Wet, M. A., Ike Mokhele, N. E., & Bouwer, W. A. J. (2008). Can engineering education in South Africa afford to avoid problem-based learning as a didactic approach? *European Journal of Engineering Education*, 33(5–6), 551–559.
- Vygotsky, L. S. (1978). *Mind in society: the development of higher psychological processes*. London: Harvard University Press.
- Zinyeka, G. (2013). Onwu and Mosimege on “Indigenous knowledge systems and science and technology education: A dialogue”: Some remaining issues. *Greener Journal of Education Research*, 3(9), 432–437.