

AN EXPLORATION INTO LEARNING DIFFICULTIES EXPERIENCED BY PHYSICAL SCIENCES LEARNERS IN SOUTH AFRICAN SCHOOLS

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ABSTRACT- one of the National Development Plan's (NDP) goal for the year 2030 is to reach a target of 450 000 learners who will be eligible for a bachelor's programme in Mathematics and Science. However, a plethora of studies and reports indicate that Physical Sciences is one of the most difficult subjects in the National Senior Certificate (NSC) examination. The study investigated learning difficulties experienced by Grade 12 learners in the learning of Physical Sciences. Diagnostic and examination reports from the past five years were examined to identify common challenges experienced by learners. The investigation revealed that learning difficulties experienced by learners were related to Proficiency in the Language of Learning and Teaching (LoLT), conceptual understanding, questions that require explanations and higher order thinking skills, difficulties in comprehension and analysis of questions, and mathematical skills. The study recommends that appropriate pedagogical approaches and practices be identified in order to address these challenges.

Key words: Science education, Physical Sciences, Learning difficulties, Science teaching, learning science, Academic skills, Science pedagogical approaches, scientific concepts.

1. INTRODUCTION

Every developing country have the hope and desire for children to obtain a good education and by this, knowledge and skills are gained from schooling, which will also lead to their personal development. South Africa, like other developing countries, has prioritised to improve access to quality of education. One of the South African educational goals is to increase the number of learners who pass Physical Sciences in Grade 12. This is outlined clearly in the Department of Basic Education's (DBE) Action Plan of 2014 that like mathematics, Physical Sciences is a subject in which performance in schools is well below where it's supposed to be for the critical skills shortages in the country and insufficient industrial innovation to be properly addressed (DBE, 2011). The National Development Plan (NDP, 2011) also emphasises that Science and technology are key to development, because scientific and technological revolution underpin economic advances, improvements in health systems, education and infrastructure. For that reason government has emphasised the centrality of mathematics and science as part of the human development strategy for South Africa.

During the past 20 years concerted effort have been made to improve the quality and output rate of mathematics and science in South Africa. In 2001, the Department of Education (DOE, 2001) developed the national strategy for improving the quality of mathematics, science and technology in General and Further Education and Training. The development of this document was aimed at strengthening the teaching and learning of science, mathematics and technology in General and Further Education and Training, using appropriate curricula, teaching methodologies and learning support materials (DOE, 2001).

In addition to the above, the Dinaledi Focus Project, the Marang Centre at Wits University, the Sci-Bono Discovery centre in Newtown, Technology Research Activity Centre (TRAC), and Mathematics, Science and Technology (MST) learning programs as well as Saturdays and holiday teaching of mathematics and science subjects were introduced (Cameron 2009).

In 2012 the Minister of Basic Education appointed a task team to conduct an investigation of the implementation of Maths, Science and Technology (MST) Strategy. The task team revealed that few provinces have clear, comprehensive and aligned MST strategies. Most provincial strategies have recently been drafted and have not permeated the provincial education systems in districts and schools. While all strategies have clear goals, many lack sufficient detail in respect of intended actions, scale, timelines and budgets to facilitate action, management and monitoring (DBE, 2012).

Recently, the Mpumalanga Government has introduced the Mathematics, Science and Technology Academy project. The academy according to the Premier of Mpumalanga Province, Mr D Mabuza, is aimed at providing an in-service learning platform for teachers to enhance their skills. It will link to satellite hubs through which it will provide direct support to focus schools to ensure that learners have access to relevant learning material, equipment and e-learning technologies (My Lowveld, 2014).

Despite all the efforts, there has been little improvement in the output rate in Physical Sciences. The table below indicate the National pass rate of Physical Sciences for the past five years.

Table 1 National Performance in Physical Sciences: 2011-2015

| Year | Number wrote | Achieved at 30% and above | % achieved |
|------|--------------|---------------------------|------------|
| 2011 | 180585 | 96441 | 53.4 |
| 2012 | 179194 | 109194 | 61.3 |
| 2013 | 184383 | 124206 | 67.4 |
| 2014 | 167997 | 103348 | 61.5 |
| 2015 | 193 189 | 113 121 | 58.6 |

The results from Table 1 indicate that from 2011 to 2013 the National pass rate for Physical Sciences has improved from 53.4% to 67.4. However, there has been a decline in the pass rate from 2013 to 2015 from 67.5 % to 58.6%. In addition, there has been a decline in the number of learners taking Physical Sciences despite the increase in the number of learners who are writing Grade 12 examinations every year. The National Planning Commission in the National Development Plan (NDP) proposes a 2030 target of 450 000 learners being eligible for a bachelor's programme with Mathematics and Science (NPC, 2013). This target will only be a dream looking at the current number of learners who pass Physical Sciences. Most universities need a minimum of 40% pass in Physical Sciences for prospective students to study a science related degree. If only 113 121 learners in 2015 passed Physical Sciences with 30% and above, it is clear that the number of learners eligible to study science degrees will even be less than a quarter of the NDP'S 450 000 target for 2030.

The point of departure here is that a lot still need to be done to improve the quality of the teaching and learning of Physical Sciences in order to attract more learners to the subject. Both the government and private sector invested a lot of financial resources with the aim of improving the quality of teaching and learning in these subjects. However, the focus has always been on resources, including human resources. Less attention has been paid on the main stakeholder, the learner. It is imperative to investigate academic challenges experienced by learners in learning Physical Sciences with the aim of suggesting the appropriate learning and teaching strategies to address such challenges. If challenges are known, it will be easier to investigate the appropriate intervention strategies to assist learners to achieve better results in the subject.

The forgoing discussion indicates the importance of investigating common academic challenges experienced by learners when learning Physical Sciences. I, therefore, report on the results of a study which investigated academic challenges experienced by South African learners when learning Physical Sciences. The research questions were as follow:

What are the common academic challenges experienced by learners in learning Physical Sciences?

What are the appropriate strategies that can be implemented to address the identified challenges?

2. LITERATURE REVIEW

For the past twenty years, a plethora of studies have been conducted on factors that contribute to higher failure rate in Physical Sciences. Mnguni (2013) investigated challenges in the teaching of natural sciences in the context of the National Curriculum Statement. In addition Muzah (2011); Dhurumraj (2013) and Ogunmade (2005) also conducted their studies into the school related factors that causes higher matriculation failure rate in Physical Sciences. However, the studies conducted were more directed to school related factors rather than challenges experienced by learners in learning Physical Sciences. Consequently, less attention has been paid on learning difficulties experienced by learners with regard to the content and how Physical Sciences is learned as a subject. Attention should be paid more on the central stakeholder which is a learner. There are several academic aspects that affect the learning of science and these deal directly with how the learner should learn the subjects. The learner may be learning in the state of the art school and be taught by the best educators in the world, but if common challenges that the learner experienced are not addressed, the performance will still be at substandard level.

There are certain academic skills that the learner may require in order to learn the subject effectively. This include, but not limited to, critical and creative skills, problem solving skills and language proficiency skills necessary for science learning. According to Tigere (2014) a proficient problem solver should be able to examine information in the problem statements, identify a potential problem and implement plans to solve the problems. A proficient problem solver should be able to recognize the associations between quantities. In Physical Sciences, the learner is expected to solve real-life problems using the laws and Principles of physics and chemistry. Therefore the learner must be able to examine the information in the problem to be able to identify which law or principle to use in solving the problem. For instance, in the example below:

The magnitude of the gravitational force exerted by one body on another body is F . When the distance between the centres of the two bodies is doubled, the magnitude of the gravitational force, in terms of F will now be....

| | | |
|---|------------------------------------|--------|
| A | $\frac{1}{4} F$ $\frac{1}{2} F$ | B C |
|---|------------------------------------|--------|

Figure 16: Example of a problem Physical Sciences Problem

It is clear that in order to do the problem above, the learner will not require rote learning strategies to solve the problem. The learner will need to recognize the associations between two quantities as it was indicated by Tigere and will have to understand Newton's law of gravitation. In this case, the quantities will be the gravitational force and the distance between the two bodies. Then the learner will need to identify what happens to the force when the distance between the two bodies is doubled. Therefore the learner will need to be a proficient problem solver in order to tackle such problems.

Another important aspect required for problem solving in Physical Sciences is critical thinking skills. Mokoena (2014) purports that it is a process where information is examined and it involves a process conceptualising, applying, analysing, synthesising and evaluating information. This is supported by Pudi (2007) that critical thinking is a specialised kind of purposeful thinking where the individual actively construct his or her own thinking and evaluating the effectiveness of the thinking according to purpose, criteria and standards. Physical Sciences learning will require critical thinking skills judging by the

problem presented above as the learner will need to analyse and evaluate the problem before it is attempted.

It is a fact that many of our learners who perform poorly in Physical Sciences may have a deficiency in critical thinking skills. This is supported by Howie (2007), that given the poor performance of learners in South Africa in literacy, numeracy, science and mathematics, deficiencies with regard to higher-order thinking abilities, including *inter alia* critical thinking skills and language abilities, are evident. Pudi (2007) further purports that in this regard, one may question whether South African learners at school are exposed to teaching practices that stimulate them to new and critical thinking. In Physical Sciences learners are expected to analyse and interpret questions when solving problems. This is especially done in Physics which requires learners to solve problems in a variety of Physics topics. For that reason, they will need critical thinking skills in order to attempt such questions.

The most important concept linked to critical thinking is language ability. Grosser and Nel (2013) argue that the ability to use language effectively is important to accomplish critical thinking. Setati (2011) also agree that language is necessary in facilitating our understanding of science by providing the cognitive framework of concepts and our entire knowledge and experience of science is mediated by language. For that reason learners' academic achievement depends on their ability to utilise language effectively for the purpose of learning.

In order for the learners to solve Physics problems, they will be expected to read and analyse the problems. According to Madileng (2007) reading skills are extremely important for academic development and therefore a skilful reader, who possesses both receptive and productive aspects of language use, can acquire a higher level of comprehension and higher order skills which are very important for academic success. A poor reader cannot be a good writer as both skills complement each other. This means that poor readers will not cope with the demands of higher vocabulary skills that are needed to learn new science concepts.

The above statements are more evident in the study conducted by Coleman (2003) to determine whether extensive reading can improve learners' comprehension skills, increase their academic achievement, and promote higher achievement in general academic subjects. In this study, one hundred and twenty-one learners comprising of extensive-readers, less-extensive readers, and non-extensive readers were identified and studied. The results indicated that extensive reading not only leads to improved achievement in comprehension, but also to improvement in general academic performance in all subjects across the curriculum.

The implication here is that academic skills such as critical thinking skills and academic literacy skills cannot be separated. Tigere (2014) agrees with the above statement that learners with high conceptual understanding in science and good command of English are likely to achieve better than learners with low conceptual understanding of science and poor command of English. For example, for problem solvers to create a mental picture of the problem, they first need to understand the problem. For this reason the medium of instruction used in presenting the problem determines the quality of problem representation.

The theoretical underpinnings of this study is based on research that always point to critical thinking skills as a prerequisite for learning science (Carneiro, 2014). To be a critical thinker, one requires the ability to think abstractly and logically as well as habits of mind. In this study the focus on critical thinking is specifically on its multi-dimensional interrelated cognitive Nature (Grosser and Nel, 2013; Facione, 2009; Halpern, 2007). This means that critical thinking skills are incorporated in science learning, however being related to most important literacies in science which include language ability and mathematics.

In conceptualizing their study on the relationship between critical thinking and academic language Grosser and Nel (2013) highlight the theory developed by Krashen and Brown (2007) which emphasise two major components of academic language proficiency. The two components include academic language used in a particular setting like the university or school as well as knowledge linked to specific subjects like Physical Sciences. In the context of this study, it is argued that in order for learners to develop critical thinking skills necessary for science learning, they will need to have good language and mathematical abilities.

The historical background of critical thinking is dated back from the Socratic Method which is regarded as the philosophy that emphasised the importance of rectifying the inconsistency and irrational thought processes as well as confused meanings, inadequate evidence, contradictory beliefs and empty rhetoric (Vaseghi, Gholami and Barjesteh, 2012 and Paul, Elder and Bartel, 1997). According to Bartel et.al (1997) Plato recorded the Socrates method and was followed by Aristotle who emphasised that only the trained mind is capable of uncovering the way we perceive things on the surface to the way they are perceived beneath the surface.

4. METHODOLOGY AND DATA COLLECTION

This was a qualitative study in which I hoped to gain some insights into academic factors affecting the learning of Physical Sciences in South Africa. Qualitative research is regarded as an unstructured approach to inquiry that is flexible with regards to the objectives, design, sample, and questions asked in order to explore the nature of a problem, issue, or phenomenon (Kumar, 2002). This was done through document analysis by studying diagnostic report of the past five years (2011-2015). These documents are available for public viewing online, and were used as the main source of data. Data from the Diagnostic reports is collected from examiners and markers reports across the country and therefore it can be concluded that data collected from these reports are valid and reliable. The department of education releases these documents every year for teachers to recognise the common errors that are committed by learners. Therefore, studying these reports will reveal common academic problems that are experienced by learners.

Document analysis is a form of qualitative research in which documents are interpreted by the researcher to report about a certain topic. Analysing documents incorporates coding content into themes similar to how focus group or interview transcripts are analysed. The documents mentioned above were analysed to establish common difficulties experienced by learners when responding to Physical Sciences question papers.

4. Results and Discussion

Detailed results are presented in five themes and the themes identified include conceptual understanding, higher order thinking, comprehension and analysis of questions, proficiency in the LoLT and mathematical skills.

4.1 Conceptual Understanding

Conceptual understanding is reported as one of the challenges in the National Senior Certificate (NSC). This is not only indicated in Physical Sciences, it is a problem that was discovered across all subjects. All of the diagnostic reports studied indicated that the majority of learners are struggling with basic concepts. The 2011 and 2015 diagnostic reports indicate that:

“There are still too many learners getting zero for pure recall questions because they had not studied enough, were not taught, did not attend class, did not have both Grades 11 and 12 textbooks, etc. There is ample evidence that learners are still not spending enough time on theory and are losing valuable marks in this part of the paper. Furthermore, the responses of a large proportion of learners are clear evidence of a serious lack of practical work in schools. (DBE, 2011). “Teachers are advised to make greater use of short informal assessment tasks in order to reinforce basic concepts and principles, e.g. short speed tests (± 10 minutes). This can be used to good effect in content relating to definitions and laws listed in the examination guideline” (DBE, 2015).

The above implications indicate that there is a great challenge in the understanding of basic concepts in South Africa. If learners are unable to answer basic recall questions like definitions, it is clear that the majority of learners do not understand what they are studying and therefore they rely on rote learning when attempting the majority of the questions. It seems like the education system is only preparing learners to attempt examination papers rather than enhancing the understanding of concepts. This is one of the main reasons for the high failing rate in higher education; since higher education focuses more on the understanding and application of knowledge (CHE, 2013).

4.2 Higher Order Thinking Skills

Higher order thinking skills is one of the requirements for learners to succeed in Physical Sciences. However, studies reveal that most of the learners may not be doing well in science due to the lack of these skills. The 2015 diagnostic reports revealed that:

“The examination papers cover the full range of cognitive levels. In many cases, candidates appear to cope only with questions involving application of routine procedures that have been taught in the classroom, and struggle with those that require more independent or creative thought” (DBE, 2015). “Questions involving scientific explanations also posed extensive problems for candidates. Lack of skills to interpret and analyse data to answer questions which require explanations led to poor performance in Q5 and Q6 (Paper 2). Another contributing factor was lack of skills to perform stoichiometric calculations”. (DBE, 2014).

All the diagnostic reports studied indicate a deficiency in attempting questions mentioned above across all subjects. As it was indicated that most learners only do well in questions that are more procedural, it is an indication that they are only trained to answer questions using previous question papers. If a question is now phrased in an unfamiliar context, then they attempt to reproduce what they were practicing from another question paper.

4.3 Difficulties in Comprehension and Analysis of Questions

One of the main purposes of Physical Sciences is for learners to be able to exploit the laws and principles in physics and chemistry to solve problems. On a daily basis, teachers work with learners in class to solve Physical Sciences problems, learners seem to recognise the problems. However, when the problem is rephrased in another context, most of the learners struggle to interpret the new situation in solving the problem. This is due to the failure of learners to interpret new situations. The diagnostic reports studied confirmed that most of the learners have deficiency in interpreting questions, especially questions that require higher order thinking. Below is an extract from the 2012, 2013 and 2014 diagnostic reports:

“The failure to comprehend and analyse the problem contributed largely to the poor performance of the weaker candidates” (DBE, 2013). “In many instances, candidates regurgitated responses to similar questions that appeared in previous question papers which did not necessarily suit the context in the question in the given examination. As a result, this worked against the candidates and contributed to loss of marks since it was evident that they had not understood the questions presented to them (DBE, 2014). “Apart from poor graph reading skills and lack of knowledge of basic definitions, candidates

tended to answer what they were drilled to answer instead of answering the question posed (DBE, 2012).

The fact that learners regurgitated responses to similar questions is a clear indication that most of the learners failed to interpret questions due to the lack of appropriate skills to tackle scientific problems. It is imperative to note that learners need to be taught on how to approach and solve a problem. Most of the learners struggle to identify the laws that they must utilise in solving a particular problem. One of the main reasons in failing to interpret questions is poor language ability which will be discussed in the upcoming sections.

4.4 Mathematical Skills

Proficiency in Mathematics is one of the fundamental skills a Physical Sciences learner must acquire. Annual assessment results indicated that as a country we are not doing well in mathematics. All the diagnostic reports studied indicate that this is a problem for many learners. The 2011 and the 2013 diagnostic reports indicate that:

“There is also a serious lack of mathematical skills like interpretation and drawing of graphs, solving equations and working with trigonometric ratios. It is also clearly evident that most learners have little or no problem-solving skills. Most learners cannot grapple with problems. Many learners stopped midway in their answers that involved calculations, possibly due to having no calculators or not having the necessary skills to use the calculators” (DBE, 2011:117). “There was evidence of poor mathematical skills and poor use of calculators contributing to the poor performance of some candidates. Poor graph reading skills and sketch graphs in Question 3 (projectile motion) were once again a problem to many candidates” (DBE, 2013: 117).

The mathematical skills problems is also evident in the National pass rate for mathematics in the NSC. For the past five years mathematics has been the worst performing subject and for subjects that require mathematics, this has become a serious problem. This is revealed in the general findings of the 2015 diagnostic report that

“in the case of subjects requiring the use of mathematical or calculation skills, it is evident that candidates lacking these skills are severely disadvantaged when it comes to earning marks for even the most basic application-type questions, and this adds to the complexity of them responding to more cognitively demanding questions” (DBE, 2015: 6).

This indicate that Physical Sciences teachers must not assume that Physical Science learners already possess the mathematical skills necessary to learn Physical Sciences. They are phased with a challenge of enhancing these skills. For example, most of the questions in Physical Sciences nowadays are presented in a form of graph or table, however most of the learners struggle to extract the data from the graph on the table when solving problems. Therefore these are the skills that need to be taught in Physical Sciences class.

4.5 Proficiency in LoLT

Language is the most powerful tool a learner needs to succeed across all subjects. However, an excess amount of studies point to inadequate language skills as one of the contributing factors to poor performance in NSC and beyond. The 2012; 2013 and 2014 diagnostic report indicate that:

“There is a strong correlation between reading skills of candidates and their ability to decode the requirements of a question. All the subject reports in this publication indicate that the poor language

skills of numerous candidates are a major reason for under-achievement. This adversely affects the ability of those candidates to interpret questions and source material, and to frame appropriate responses to questions. This was observed in learners' inability to correctly interpret the verbs used in a question and their understanding and application of the correct subject terminology" (DBE, 2014). "A lack of linguistic skills required to express themselves in simple and proper paragraphs were evident in the responses of candidates across all subjects. Candidates displayed inadequacies regarding the skills of reading, comprehension, and analysing, evaluating and applying information to either make decisions or solve problems (DBE, 2012). A lack of understanding of the action verbs used in the questions, led to inaccurate interpretation of questions by candidates. This can also be attributed to poor language competencies especially in the language of assessment (DBE, 2013).

The majority of learners in South Africa learn in the language that is not often spoken at home. However, since English has taken a position as the "lingua-franca" in South Africa, it is important that English as the learning language be developed. English First Additional Language must not be taken as an ordinary subject, it should be given a priority as it is one of the subjects that will assist learners to develop Cognitive Academic Language Proficiency Skills (CALP) that are necessary for learning content subjects.

5. CONCLUSIONS AND RECOMMENDATIONS

The findings indicate that Physical Sciences educators have to rethink their teaching in order to accommodate the type of learners that are in the system today. The type of learners we teach today lack basic academic skills like reading, writing and numeracy. Incorporating different strategies to accommodate the challenges specified in the findings is a very process in which improvement in academic performance can be observed. When a new topic is introduced all new concepts must be clarified to learners. This can be done by ensuring that each topic is contextualised to enhance understanding.

Another way of enhancing basic concepts is allowing learners to write the definition in their workbook rather than relying on the textbooks for definitions. Glencoe (2005) agree that writing about newly-acquired content strengthens understanding, while allowing students to make connections with prior learning. Van Staden, (2010: 24) also agree that students in turn also discover and distinguish patterns in language that they can use in order to make their understanding and comprehension of the work easier. Writing in the science classroom can also assist learners in mastering questions that require higher order thinking and explanation. This can be done by allowing learners to model an explanation for a particular concept. Hohenshell (2004) argues that writing to learn strategies can be used as a medium to practice and improve science literacy skills, serving as a means for thinking and reflection, which promote students' efforts in transforming knowledge.

Problem based learning strategies can be employed when teaching learners to solve problems in class. It is imperative that this method be studied in order to have an understanding on how it can be implemented in the classroom. Learners also need mathematics in solving Physical Science problems. An educator can identify the mathematical skills needed in each topic. By doing so the teacher can ensure that these skills are taught since learners will need them in that topic. In other words, mathematics teaching must not only be confined in the mathematics classroom. It is the responsibility of the science teachers to make sure that these skills are enhanced.

As an experienced science teacher I have noted that the majority of mathematics and science teachers in South Africa are the most hardworking teachers as compared to teachers in other disciplines. In most cases, they are the first to arrive at school and the last to leave the school. However, the question is, do these teachers really plan for extra class. If these extra lessons can be used to enhance the skills mentioned above, this can make a great difference. For example, a science teacher can plan a lesson where he/she will only teach mathematics skills necessary for science learning. Otherwise the educator

can also plan a lesson to pay attention to the understanding of basic concepts in Physics or chemistry. This can assist rather than only planning an extra class to revise previous question papers which are often regurgitated by learners during examinations.

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