

Senior Phase Science Teachers' Pedagogic Content Knowledge of the Periodic Table: A Case Study of Selected Schools in KwaZulu-Natal, South Africa

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Abstract— Learner performance in science is cause for concern in South Africa. Science teachers' pedagogic content knowledge plays a significant role in learner performance. This paper examines teacher pedagogic content knowledge in a key area of the Natural Science curriculum in the Senior Phase of the General Education and Training (GET) band, namely the Periodic Table. Understanding how the periodic table of elements is organized and how to read information from it is fundamental for understanding chemistry [1]. This study forms part of a larger study that compares the pedagogic content knowledge of South African and Zimbabwean teachers concerning the Periodic Table. A qualitative approach was used to collect data from secondary schools science teachers in KwaZulu-Natal. The data indicates that pedagogic content knowledge of teachers concerning the Periodic Table is limited due to factors such as inadequate preparation of lessons by teachers, inappropriate deployment within the school, limited availability of resource materials and support from the department of education. Based on the findings, teachers will be observed teaching lessons on the Periodic Table so that an assessment can be made of their pedagogical content knowledge, in order to design and implement strategies to improve teacher PCK, thus improve teaching and learning of science.

Index Terms— Learner Performance, Periodic Table, Teacher Training.

I. INTRODUCTION

Almost two decades after the end of apartheid, it is claimed that many of South African schools can be labelled as dysfunctional. Recently, the World Economic Forum ranked South Africa 137th out of 139 countries in terms of mathematics and science education. This is in spite of the fact that education gets the biggest share of the country's budget and spending per learner far exceeds that of any other African country. The dismal state of affairs has in part been ascribed to poor teacher education, as well as a broad national concern over the poor state of teachers' knowledge, particularly their subject content knowledge. The President's Education Initiative research project [2] concluded that the limited conceptual knowledge of teachers – including poor grasp of subject - was the most important challenge facing teacher education in South Africa. Hence, this study seeks to ascertain how teachers acquire pedagogic content knowledge in order to teach science effectively. For the purpose of this study, the aspect of the curriculum chosen was the Periodic

Table since understanding of the Periodic Table is fundamental in understanding chemistry.

II. REVIEW OF LITERATURE

Pedagogical Content Knowledge (PCK) is a result of the interaction of content and pedagogy. It is knowledge about the content that is derived from consideration of how best to teach it. For a particular topic, it includes knowledge of:

(i) What makes the topic easy or difficult to understand—including the preconceptions about the topic that students bring to their studies.

(ii) Those strategies most likely to be effective in reorganizing students' understanding to eliminate their misconceptions.

(iii) A variety of effective means of representing the ideas included in the topic analogies, illustrations, examples, explanations, and demonstrations [3].

PCK is an acknowledgement to the importance of the transformation of subject matter knowledge per se into subject matter knowledge for teaching. By and large, PCK has been described as the knowledge used to transform subject matter [3],[4],[5],[8]. Thus, the development of PCK involves a dramatic shift in teachers' understanding "from being able to comprehend subject matter for themselves, to becoming able to elucidate subject matter in new ways, reorganize and partition it, clothe it in activities and emotions, in metaphors and exercises, and in examples and demonstrations, so that it can be grasped by students" [3]

Five components of PCK for science teaching:

A. Orientations to Teaching Science

This component refers to teachers' beliefs about the purposes and goals for teaching science at different grade levels [5]. Since the transformation of teacher knowledge from other knowledge domains into PCK is not a straightforward task but an intentional act in which teachers choose to reconstruct their understanding to fit a situation [9],[10]. orientations to teaching science influence PCK construction by serving as a concept map that guides instructional decisions, the use of particular curricular materials and instructional strategies, and assessment of student learning [10].

B. Knowledge of Students' Understanding in Science

To employ PCK effectively, teachers must have knowledge about what students know about a topic and areas of likely

difficulty. This component includes knowledge of students' conceptions of particular topics, learning difficulties, motivation, and diversity in ability, learning style, interest, developmental level, and need.

C. Knowledge of Science Curriculum

This refers to teachers' knowledge about curriculum materials available for teaching particular subject matter as well as about both the horizontal and vertical curricula for a subject [5]). This component is indicative of teacher understanding of the importance of topics relative to the curriculum as a whole. This knowledge enables teachers to identify core concepts, modify activities, and eliminate aspects judged to be peripheral to the targeted conceptual understandings. Reference [4] called this understanding "curricular saliency" to point to the tension between "covering the curriculum" and "teaching for understanding."

D. Knowledge of Instructional Strategies and Representations for Teaching Science

This component consists of two categories: subject-specific strategies and topic-specific strategies [9]. Subject-specific strategies are general approaches to instruction that are consistent with the goals of science teaching in teachers' minds such as learning cycles, conceptual change strategies, and inquiry-oriented instruction. Topic-specific strategies refer to specific strategies that apply to teaching particular topics within a domain of science.

E. Knowledge of Assessment of Science Learning

Reference [11] stated, "Every educational event has a learner, a teacher, a subject matter, and a social environment. I would like to suggest a fifth element – evaluation" (p. 54). In accordance with this, knowledge of assessment is an important component of PCK. This component is comprised of knowledge of the dimensions of science learning important to assess, and knowledge of the methods by which that learning can be assessed [12]. Evaluation includes knowledge of specific instruments, approaches, or activities.

III. METHODOLOGY

A. Research Design

This study was a multiple case study of five natural science teachers who are teaching at different schools in the same circuit in the KwaZulu-Natal province of South Africa.

B. Data Collection

Reference [13] argues that the complexity of teachers' knowledge cannot be captured by a single instrument. Assessment of PCK, in particular requires a combination of approaches that can collect information about what teachers know, what they believe, what they do, and the reasons for their actions [14]. Hence data was collected from multiple sources including semi-structured interviews, and documents such as lesson plans, assessment tasks, teachers' written reflections, students' work samples, and researcher's field notes.

C. Data Analysis

The data were analysed through the constant comparative method where the data analysis focused on the identification of regularities or patterns in interview transcripts through an interactive process during which the data were constantly compared [15]. In the discussion whenever reference is made to a teacher number the

teacher number corresponds to the school number (eg. teacher 2 is from school 2).

IV. FINDINGS AND DISCUSSION

A. Findings from document analysis and interviews with teachers

School 1

1. Curriculum document:

The curriculum document (Curriculum and Assessment Policy Statement (CAPS) Natural Sciences grades 7 8, 9) was available in the teachers file.

2. Work schedule/scheme of work:

The school uses the work schedule provided by the district. This schedule covers the work that has to be done for the four terms. The teacher indicated that "I was given the work schedule by my Head of Department and asked to follow it"

3. Lesson preparation:

The teacher uses a lesson plan template provided by the district. This template is specifically for Natural Science lesson planning. Lesson planning has to be done using the following headings: Date, topic, teacher activities, learner activities, resources and assessment. There is also a section at the end of the template for reflections. Template attached as appendix 1. The teacher's preparation of the lesson is brief and superficial. None of the lesson plans indicated the content of that was to be taught. The teacher said that "I do not see any need to indicate the content of the lesson in the lesson plan because it is in the text book and learners can copy it from the textbook."

4. Textbooks:

The textbook used is 'Spot On' Natural Science and the teacher said that "there were no other textbooks available in the school."

5. Worksheets:

There was no evidence of any worksheets used to teach the periodic table

6. Homework:

Students complete a project that is set for schools in the cluster.

7. Learner note/exercise books:

Learners use an exercise book to take down notes. They also do their homework in this book

8. Assessment:

All assessment tasks are set by the cluster, including control tests, June examinations and projects. "All assessment tasks are provided to us by the cluster, and I do not know who sets these assessment tasks. All I know is that I must teach according to the schedule provided so that my learners will be prepared to the assessment tasks set," was the

comment made by the teacher regarding assessment. While this might be an attempt to standardise assessment, teachers ought to set their own tests to cater for the context within which they teach.

9. Resources to teach periodic table:

There are no specific resources available at the school.

School 2

1. Curriculum document:

The curriculum document (Curriculum and Assessment Policy Statement (CAPS) Natural Sciences grades 7 8, 9) was available in the teachers file, who said that “ I obtained the Natural Science CAPS document from the subject advisor, but I saw no need to read this document as I was told to follow the work schedule provided by the department.”

2. Work schedule/scheme of work:

The school uses the work schedule provided by the district. This schedule covers the work that has to be done for the term. This teacher explained that “ I would like to change the order of the topics but because we write common tests I cannot do so.”

3. Lesson preparation:

The teacher prepared the lesson using her own format. Lesson planning has to be done using the following headings: Date, topic, teacher activities, learner activities, resources and assessment. There is also a section at the end of the template for reflections. The teacher’s preparation of the lesson is detailed. The teacher explained that “it takes me a long time , sometimes four or five hours over the weekend to prepare lessons for the week.”

4. Textbooks:

The textbook used is ‘Spot On’ Natural Science.

5. Worksheets:

A photocopied periodic table from the text book was provided to learners. The teacher has made no attempt to prepare her own worksheet. A copy of the periodic table was given to learners. The teacher said that “I photostat parts of the textbook that I think are important and give it to learners because we do not have sufficient textbooks for all the learners.”

6. Homework:

Students complete a project that is set by schools in the cluster

7. Learner note/exercise books:

Learners use an exercise book to take down notes. They also do their homework in this book. The teacher provided the learners with a chalkboard summary which was copied by learners in the exercise book.

8. Assessment:

All assessment tasks are set by the cluster, including control tests, June examinations and projects

9. Resources to teach periodic table:

There are no specific resources available at the school and the teacher said that:“I have asked the principal to allocate fund to purchase science resources and equipment but his response was that the governing body needs to be approached to allocate funds to equipment. To date there has been no response from the governing body or the principal.”

School 3

1. Curriculum document:

The curriculum document (Curriculum and Assessment Policy Statement (CAPS) Natural Sciences grades 7 8, 9) was available in the teachers file.

2. Work schedule/scheme of work:

The school uses the work schedule provided by the district. This schedule covers the work that has to be done for four terms

3. Lesson preparation:

The school uses a lesson plan template provided by the district. This template is specifically for Natural Science lesson planning. Lesson planning has to be done using the following headings: Date, topic, teacher activities, learner activities, resources and assessment. There is also a section at the end of the template for reflections.. The teacher’s preparation of the lesson is brief and superficial. The teacher mentioned that “it does not take me a long time to prepare lessons; I just complete my lesson plan using the space provided on the template. That is all I need to do.”

4. Textbooks:

The textbook used is ‘Spot On’ Natural Science. The teacher said that “I do not know where I will be able to find any additional information to teach the periodic table.”

5. Worksheets:

No evidence of any worksheets used to teach the periodic table

6. Homework:

Students complete a project that is set by schools in the cluster

7. Learner note/exercise books:

Learners use an exercise book to take down notes. The teacher said that “I only give learners notes on the chalkboard if the textbook does not have information on the topic taught.” They also do their homework in this book

8. Assessment:

All assessment tasks are set by the cluster, including control tests, June examinations and projects

9. Resources to teach periodic table:

There are no specific resources available at the school for the teaching of Natural Science. The teacher indicated that "the science equipment that is available at the school is used by the grade twelve teachers."

School 4

1. Curriculum document

The curriculum document (Curriculum and Assessment Policy Statement (CAPS) Natural Sciences grades 7 8, 9) was available in the teachers file.

2. Work schedule/scheme of work

The school uses the work schedule provided by the district. This schedule covers the work that has to be done for the four terms

3. Lesson preparation

The school uses a lesson plan template provided by the district. This template is specifically for Natural Science lesson planning. Lesson planning has to be done using the following headings: Date, topic, teacher activities, learner activities, resources and assessment. There is also a section at the end of the template for reflections however the teacher did not complete this aspect. The teacher's preparation of the lesson was in greater detail. She said that "it takes a great deal of time to prepare a lesson because the only resource I have is the textbook."

4. Textbooks

The textbook used is 'Spot On' Natural Science, Publisher is McMillan

5. Worksheets

There was no evidence of any worksheets used to teach the periodic table

6. Homework

Students complete a project that is set by schools in the cluster. The teacher mentioned that "learners do not like to do homework, but projects seem to motivate them."

7. Learner note/exercise books

Learners use an exercise book to take down notes. They also do their homework in this book

8. Assessment

All assessment tasks are set by the cluster, including control tests, June examinations and projects. The teacher mentioned that "I would like to set my own test for my learners, because they perform poorly in the common tests."

9. Resources to teach periodic table

There are no specific resources available at the school

School 5

1. Curriculum document

The curriculum document (Curriculum and Assessment Policy Statement (CAPS) Natural Sciences grades 7 8, 9) was available in the teachers file.

2. Work schedule/scheme of work

The school uses the work schedule provided by the district. This schedule covers the work that has to be done for the four terms. The teacher mentioned that "in the past I drew up my own work schedule, with the assistance of my HOD and we were able to complete the syllabus in time. Now we are required to follow a schedule and it does not consider that we are involved in other activities at our school."

3. Lesson preparation

The school uses a lesson plan template provided by the district. This template is specifically for Natural Science lesson planning. Lesson planning has to be done using the following headings: Date, topic, teacher activities, learner activities, resources and assessment. There is also a section at the end of the template for reflections. The teacher's preparation of the lesson is brief and superficial

4. Textbooks

The textbook used is 'Spot On' Natural Science. The teacher said that "the textbook does not always provide information at the level of the learners understanding, therefore I have to give learners notes on the board."

5. Worksheets

There was no evidence of any worksheets used to teach the periodic table

6. Homework

Students complete a project that is set by schools in the cluster.

7. Learner note/exercise books

Learners use an exercise book to take down notes. These notes were a reproduction of the information in the textbook. They also do their homework in this book

8. Assessment

All assessment tasks are set by the cluster, including control tests, June examinations and projects

9. Resources to teach periodic table

There are no specific resources available at the school. The teacher said that "I have tried several times to request for science resources but have been told that there are other more important things to attend to at the school."

V. DISCUSSION

From the examination of documents it is evident that all school in the circuit follow the directives given to them by the

subject advisors. Educators were very co-operative in providing information and documents that they had, however copies of lesson plans were only provided by 2 of the schools. The other schools indicated that their teachers used the template provided by the department. The lesson plan template provided by the department was found to be far from adequate for teachers to plan a lesson in any detail. Most of the documents used by schools in this cluster were provided by the subject advisor of the district. Common assessment tasks were used by all schools. Besides the textbooks schools had very little other resources for science teaching. None of the schools have a science laboratory.

In order to acquire adequate PCK to teach the Periodic Table the teacher need firstly to “interact with the curriculum.” By interacting with the curriculum I mean that teachers must read, interpret and formulate or design their own work schedule in relation to their particular school context, secondly, they must plan and prepared detailed lessons, using a variety of teaching methods to cater for the needs of their learners. Reference [4] refer to this as “curricular saliency” Achievable aims must be formulated for lessons and attention must be given to outlining in great detail, the content of the lessons. In one school the lesson format provided only a single line space for the teacher to record the lesson content. The teacher only uses the space available on the lesson template to prepare the lesson. Teachers gave no description of how they structured their lesson, they only indicated, very briefly teacher activities and learners activities. There is also no indication of strategies or methods employed by the teacher to teach the lessons. None of the teachers reflected on their lessons. Teacher 5 said that “I do not have time to do lesson reflection because I have to mark exercise and test for six different classes that I teach. Each of these classes has over 40 learners per class. I do not see a need to reflect on the lesson because I will not be using this lesson plan again, so why bother to reflect on the lesson.” It is evident from this comment that teachers do not realise the importance of lesson reflections in the development of their pedagogical content knowledge.

A third crucial aspect towards development of adequate PCK is the ability of a teacher to prepare and administer assessment tasks based on what he/she has taught learners (following the guidelines provided in the curriculum document.) Preparing assessment exercises provided the teacher with “knowledge of the methods by which that learning can be assessed” [12]. Presently, in all of the schools teachers are not preparing their own assessment tasks. The common assessment tasks that were analysed indicated that there was a variety of question types ranging from recall of knowledge to analysis and synthesis type question. There were also questions based on practical work that teachers need to do. The teachers indicated that their learners performed poorly in these common tests because they were not exposed to answering these types of questions.

All of the teachers interviewed, indicated that there were no resources and equipment to do practical work in science. Teachers indicated that they did not do any practical work with their learners. Aspects of the curriculum that required

practical work was done “as a theory lesson” as described by one of the teachers. Teacher did not even have a display chart of the periodic table. One teacher indicated that she photocopied the periodic table from the textbook and used it to teach the section on the periodic table.

VI. CONCLUSION

The data gathered from interviews with teachers and analysis of documents indicates that pedagogic content knowledge of teachers concerning the Periodic Table is limited due to factors such as inadequate preparation of lessons by teachers, insistence by education authorities in this circuit that all science teachers follow their directives strictly (without any deviation) and limited availability of resource materials and support from the department of education. Based on the findings, teachers will be observed teaching lessons on the Periodic Table so that an assessment can be made of their pedagogical content knowledge, in order to design and implement strategies to improve teacher PCK, thus improve teaching and learning of science.

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