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PROBLEMS WITH PERIODIC TABLE THEORY-PRAXIS IN CHEMISTRY TOPICS TEACHING

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ABSTRACT

The two main chemical concepts that are the subject of this investigation are chemical bonds and related reactions. This research examines how the periodic table concept can help teachers improve science teaching. To help students understand the contents of the periodic table and the helpful information its settings provide students. This study looks at how teachers use the periodic table in class. The study focused on schools as a single case and adopted a qualitative methodological approach. Two physics teachers participated. It was found that according to teachers, the periodic table may impact how they use or ignore its use when teaching students about its content or as a framework for understanding material and chemical reactions. Therefore, the concept of the periodic table can help teachers improve the quality of teaching. There needs to be more in-depth research on the apparent relationship between teacher knowledge representation in chemistry and teachers' approaches to teaching using the periodic table.

MASALAH TEORI-PRAKTEK TABEL PERIODIK DALAM PEMBELAJARAN KIMIA

Kata Kunci:

Ikatan kimia
Reaksi kimia
Tabel periodik
Praktek
Teori

ABSTRAK

Dua konsep kimia utama yang menjadi subjek penyelidikan ini adalah ikatan kimia dan reaksi terkait. Penelitian ini melihat bagaimana konsep tabel periodik dapat membantu guru meningkatkan pengajaran sains. Untuk membantu siswa memahami isi tabel periodik dan informasi bermanfaat yang diberikan pengaturannya kepada siswa. Penelitian ini melihat bagaimana guru menggunakan tabel periodik di kelas. Studi difokuskan pada sekolah sebagai kasus tunggal dan mengadopsi pendekatan metodologi kualitatif. Ada dua guru fisika yang berpartisipasi. Ditemukan bahwa menurut guru, tabel periodik dapat mempengaruhi bagaimana guru menggunakan atau mengabaikan penggunaannya saat mengajar siswa atau sebagai kerangka kerja untuk memahami materi dan reaksi kimia. Dengan demikian, konsep tabel periodik dapat membantu guru meningkatkan kualitas pengajaran. Perlu penelitian yang lebih mendalam tentang hubungan yang jelas antara representasi pengetahuan guru dalam kimia dan pendekatan guru untuk mengajar menggunakan tabel periodik.

1. INTRODUCTION

The Periodic Table largely shapes the content of the field of chemistry. Using it as a teaching and learning tool for chemistry ideas is crucial. The periodic table is a teaching and learning aid outside of chemistry. It can investigate anything made of matter in many other disciplines. Despite the periodic table being a helpful teaching tool for teachers, many students still have difficulty comprehending areas like chemistry [1]. Many students find understanding and learning chemistry fundamentals difficult and abstract [2]. Despite students' lack of specificity on the causes and/or origins of their difficulties with learning chemistry, it is argued in this article that those difficulties are due to a lack of knowledge and/or understanding of the periodic table system.

Research studies in science and chemistry show that a lack of conceptual understanding is the main issue preventing students' performance and ultimate achievement [3], [4]. Periodic table learning studies reveal additional and diverse hurdles to conceptual knowledge [5]. For instance, some of these problems involve teachers overlooking the details of the periodic table system and corresponding misconceptions in their teaching [6]. It makes sense that a student's perspectives on mastering a particular subject or topic would influence their development [7].

It is evident that learning science, in general, and Chemistry, in particular, present many difficulties. It has several elements because it pertains to more than simply the nature of the subject or the students. The surroundings for learning are also included. There are thus numerous instances in which the periodic table's application could enhance students' comprehension of chemistry. The idea is to facilitate learning. Teachers should focus on and embrace the critical aspect of how students learn. In other words, when students study chemistry concepts, we need to link their knowledge construction and representation processes to their capabilities with the periodicity of elements. Teachers will be able to track and identify specific students' conceptual breakthroughs with their capacity to make connections. Teachers must therefore be able to recognize suitable approaches for accurately integrating periodic table information into scenarios that students are familiar with from their everyday lives if they are to improve conceptual comprehension in chemistry learning.

Prior Chemistry knowledge and experiences may be part of a learner's cognitive framework [8]. These factors affect how effectively students can use new knowledge. Therefore, teachers must assist students in understanding the usefulness of the periodic table in learning from genuine real-world applications if they are to conceptually understand chemistry ideas. There is little doubt that various techniques and tools are necessary to comprehend the complexity of teaching and learning. Therefore, we cannot claim to have all the methods and materials required to fully understand the benefits of using the periodic table to teach and learn all or a portion of chemistry fundamentals. Teaching is complex and demanding if education aims to develop conceptual understanding and associated socio-scientific challenges that conceptualize a scientifically literate person [9]. This qualitative method design study's objective is to establish the periodic table system's value to teachers in light of this. The study would concentrate on the methods used in Grade 11 to teach and learn about chemical reactions and bonding. We asked the following research question to ascertain if teachers use the periodic table as both content and a tool to assist students in understanding the links between the periodic table's substance and the helpful information its arrangement delivers to the student: what are teachers' understanding of and approach to the use of the periodic table in the teaching of chemical bonding and related reactions?

Research related to the exploration of teachers' understanding of subject topics has been carried out a lot, including analysis of understanding theoretical concepts and chemistry practicum in prospective teachers [10], teachers' understanding of arithmetic concepts [11], teachers' knowledge of geography learning [12], teachers' understanding of physics material [13], [14]. Still, there has been no research on teachers' understanding of using the periodic table in chemical bonds and reactions. This research helps teachers and students apply the periodic table more effectively in learning.

This research aims to discover the teacher's understanding of theory and practice in using the periodic table in chemistry lessons. Previous research was carried out in other scientific fields, so this research focuses on chemistry. The periodic table has long been a reference in chemistry learning, but in practice, it is often not used as a resource in learning and is only used as a reference.

2. METHODS

In this study, a qualitative approach was used. An interpretative multiple-case study focusing on a specific school with unique characteristics made up the study's design. Two teachers from the same school are involved in individual cases. Consequently, it is a multiple-case study [15]. In essence, the design will be distinguished by both the apparent within-case and between-case attributes [16]. The researchers carefully analyzed and understood the problem at hand using this approach and design. The study investigated how teachers might have conceptualized and applied knowledge of the periodic table to teach bonding and chemical processes. The study looked at how the periodic table, or some of its components, can be used to teach and learn about chemical processes and bonding.

The investigation's target population was the school's grade 11 physical sciences teachers. As a result, the sample (cases) for the study was selected from this group. The participants, two teachers, and one of the researchers all worked at the same institution or school. Throughout the data collection process, Grade 11 students were taught Chemistry by the two physical science teachers, who have a combined twenty-three years of experience teaching students in grades eight through twelve. Chemistry is a subject covered in Physical Science subject. Differentiated teaching experiences among the participants may increase the value of the study according to the rationale for the teacher selection procedure.

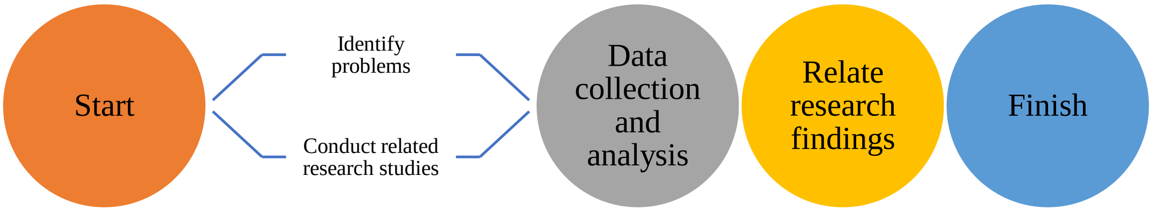

Figure 1. Research Procedure

3. RESULTS AND DISCUSSION

The researcher and the participating science teachers were involved in the data collection process, using their unique teaching circumstances as examples. The science teachers were identified as experimental teacher 1 (T 1), possessing a B. Ed: HON in natural sciences and at least 20 years of classroom experience. The experimental teacher 2 (T 2) has at least three years of teaching experience, a BSc in Chemistry, and a PGCE in science teaching. Several observations were made during the data-gathering process.

In other words, while the two participating teachers supported intervention teaching of the periodic table, the researcher oversaw them. The two teachers' teaching approaches were examined and contrasted. As a point of reference, the participating teachers also taught the same concepts. The two teachers' comparisons were made to see what types of qualitative changes there have been (Appendix A; Table 1). The two participant teachers may connect with students in various ways because of their different pedagogical strategies and uses of the periodic table.

The responses to the research question can be used to summarize the outcomes and findings on the several elements of the *integrated analytical framing* of the conception concept. *What are teachers' understanding of and approach to the use of the periodic table in teaching chemical bonding and related reactions?* The ideas from Hewson & Hewson [17] and Thompson [18] are incorporated into the analytical framework. By using this framework, the researchers were able to compile and present the findings regarding how the teachers conceptualized the periodic table as both content and a tool for chemistry teaching and learning. The shortened form synthesizes the many parts of thought (Appendix A; Table 2) to highlight the uniqueness of conceptual comprehension and the significance of the situatedness of the influence of learning environments and/or contexts. The results will be presented to the two teachers separately. The seven components of the combined concept for the two teachers are condensed (see Table 2; Appendix A) in the summary findings.

3.1 Teacher 1: Periodic Table as Content and Tool

The multiple facets of this teacher's comprehension of the periodic table as both a tool and content are difficult to discern. The teacher does not comprehend the periodic table's two sides very well. The teacher, for instance, was unable to recognize the distinction between what would be considered content and the notion of using the periodic table as a teaching tool for chemical bonding and associated reactions to produce new compounds. Most of the teacher's explanation of the periodic table took place at the declaration level, where students had to identify and/or compute specifics such as the molecular mass, atomic mass, atomic number, and the number of protons and electrons in an atom.

This teacher's explanation of how the periodic table was made does not address the idea that the periodic table connects the components (such as elements) in their exact placements in groups and periods as metals, non-metals, or metalloids across the system (Table 1 and 2; OBS 102). As a result, the teacher cannot communicate to the students an organized conceptual understanding of the PT as both a subject material (content) and a tool for explaining the learning of matter and the changes it undergoes (system). The teacher would find it challenging to draw a direct connection between the incorporated content of the PT and the development of bonds or elements' reactivity to enhance chemical bonding and atom-to-atom reactions and produce innovative chemical compounds with various chemical formulae.

Furthermore, it was clear that the teacher could not evaluate the information on chemical bonding using the PT approach. It appears that the teacher is selective about the knowledge that must be learned, and in this situation, that knowledge is declarative, even though the students may not be aware of it [19]. The integrated system that should cover both the content and tool conceptions in chemistry teaching and learning does not include this information, which is merely a small part of it. The term "adapted teaching" is widely used to describe the teaching of selective content. Adaptive teaching is when a teacher teaches students based on what they already know rather than what the curriculum prescribes [20].

The teacher's viewpoint on applying the PT system in the classroom is crucial to its conception. The techniques and skills necessary to teach a subject effectively conflict with some teachers' principles. These might prevent meaningful learning and limit the variety and level of teaching needed to achieve the stated learning objectives. The best option to use the PT in this situation is to explain how to learn about chemical bonds and/or related processes and the teaching and learning materials. The teacher's use of PT in the classroom appears to be focused on quantification. These were made abundantly clear through interactions with the students and their work. The teacher assumes that the students have certain qualities and/or prior knowledge of the periodic table or how to use it. Most teachers have limited experience teaching science or the periodic table because most instructional strategies are teacher-centered.

3.2 Teacher 2: Periodic Table as Content and Tool

Concepts are essential for knowing because they enable us to arrange our knowledge and establish meanings [21]. It was not immediately evident how this teacher perceived the periodic table as both a teaching tool and information about the substance and its changes, even though she had some relationship to the data in the periodic table. The teacher could interact with the system and content of the periodic table, but not in a way that would enable her students to learn meaningfully. The teacher had an approach of trying to control all activities because her teaching philosophy represents a strong personality. She was, therefore, more invested in her student's education than in her own. The students were the ones who benefited from all the teacher's knowledge. It is clear from this that the teacher's inability to understand how to teach science using the periodic table indicates that they did not have a deep understanding of how scientific knowledge is organized.

Additionally, the teacher could not recognize and use all of the elements included in this method since she could not differentiate between using the periodic table as a tool and as content. Furthermore, the teacher may not have been able to teach and use the bulk of the periodic table's properties as they relate to how chemical bonds are created and, consequently, how changes in matter take place due to her limited understanding of the periodic table system. Our comprehension of chemical bonding and associated reactions is aided by both the information included in the periodic table and the system it serves as a tool to describe. Chemistry can still be taught, but only by having the students memorize facts by heart. In other words, the knowledge students pick up from her classes might not always be helpful or appropriate.

The two teachers share a very similar perspective on the periodic table as a tool and a matter. They are primarily familiar with periodic table elements that are unnecessary system components. As a component of the periodic system, each element appears to be distinct from the others. The connections between the various components do not seem to be particularly important. The two teachers completely ignore the idea that the periodic table is a depiction of the same content that they must understand and use in their science lessons. It is not immediately apparent from their periodic table use that both characteristics come from the same table. For instance, teacher 2 (T 2) had a hazy knowledge of the periodic table's role as a teaching tool and source of information regarding chemical bonding and/or related chemical changes. Therefore, it could confuse the learners if she tries to use it to teach the PT as material or as a tool to explain abstract concepts.

Teachers' ideas about the subject material and the learners they are supposed to teach may impact how they teach and must be accurate to conclude [17]. The results of this study imply that there might be a connection between some features of teachers' conceptions and how their learners would acquire comprehension while learning, leading them to misinterpret the concepts that the teachers were attempting to convey.

The main conclusion from the research question indicates that both teachers have a general and limited comprehension of the periodic table as a subject matter and teaching tool. They regard just the periodic as a reference tool in their teaching because that is how they see it. Additionally, there are apparent but inconsistent connections between their theory and praxis in their notions connected to teaching. These hazy connections between the tool and the material may harm their teaching, hinder learners' grasp of crucial ideas or associated chemical processes, or both.

Gardner uses his performance view of understanding to make a strong case for understanding for both teachers and learners [22]. Gardner suggested 1997 that "…when it comes to understanding, the emphasis falls properly on the performances that can be observed, critiqued, and improved" (p.73). In other words, the ability of teachers to interpret the content and apply it appropriately must be used to assess their level of comprehension. To ensure that their learners' learning of chemistry is meaningful, teachers in this study must be able to interpret the information in the periodic table and apply its system to their teaching. In his argument, Gardner does not seek to divide teaching and learning into two distinct conceptual and practical processes. It is instead intended to highlight Vygotsky's concept of object-practical human activity [23]. The cultural-historical activity theory (CHAT) explains and assists in comprehending the human mind's origins, architecture, and contents (p.189). Because of this, the combined framework proposed by Thompson [18] and Hewson and Hewson [17] was used in this study to clearly describe the human minds of the teachers as influenced by their historical backgrounds and teaching cultures throughout their careers. Their conceptions of the periodic table are historical and were mainly conceived in particular systems (cultures) of education.

This study aimed to better understand how teachers use the periodic table as a teaching tool and curriculum content when teaching chemistry. This analysis characterized the teachers' conceptions of matter (i.e., as elements in the periodic table) and its changes (i.e., as informing the formation of bonds and chemical reactions) concerning the periodic table as both contents (i.e., its elements) and tool (i.e., the system by which meanings are constructed). In other words, the teachers' conceptions of the periodic table's elemental content, structure, and system must have explained how matter behaved and changed to form new chemical compounds occurred and informed their learners in their teaching contexts. As a result, these allowed learners to actively construct knowledge (constructivism) rather than merely being imparted by a teacher, and the teacher acts as a guide and/or encourages their learning [24]. Therefore, a teacher cannot effectively teach chemistry without having a working knowledge of the periodic table.

The results of this study provide an overview of the teacher's understanding of the use of the periodic table as a source of information in learning which contains knowledge about chemical bonds that forms the basis of learning that will be studied later. This description shows the teacher's lack of understanding regarding this matter, as evidenced by the explanation given in a declarative manner so that students are difficult to understand. The teacher assumes that students already have an initial understanding of the periodic table. The teacher only focuses on the material being taught by using the periodic table as a reference, even though it contains the relationships between elements and metalloids between systems. The main conclusions from the research questions indicate that both teachers have a general and limited understanding of the periodic table as a subject and teaching tool. They only consider periodicals as a reference tool in their teaching because that's how they see it.

Moreover, their understanding of teaching has a clear but inconsistent relationship between theory and praxis. Unclear relationships between these tools and materials may harm their teaching, hindering students' understanding of important ideas or associated chemical processes, or both. In previous studies, research was carried out more broadly regarding the understanding or competence of chemistry teachers only [25]. This study specifically discussed chemistry teachers' understanding of the use of the periodic table. This research needs to be studied more deeply regarding the knowledge representation of chemistry teachers. This is to provide a solution to this problem.

4. CONCLUSION

The primary finding from the study question suggests that neither teacher has a comprehensive understanding of the periodic table as a subject or teaching tool. Because that is how they see it, they only utilize the periodic table as a point of reference rather than as a resource to infer meanings for their lessons. Additionally, there are clear but erratic linkages in their conceptions of teaching between their theory and praxis. These unclear linkages between the tool and the subject matter may negatively affect how they teach, impair students' understanding of important concepts or related chemical processes, or both.

The purpose of this study was to gain a better understanding of how chemistry teachers use the periodic table as a teaching resource and piece of curriculum content. This study describes the teachers' views of matter (i.e., the elements of the periodic table) and its transformations (i.e., how bonds are formed and chemical processes take place) in connection to the periodic table as both a tool and a source of information, that is, its elements) and the system by which meanings are constructed. To put it another way, the teachers' ideas about the elements in the periodic table's content, structure, and system had to have clarified how matter acted and changed to produce new chemical compounds and how this happened and informed their students in their educational contexts. In conclusion, a teacher cannot properly teach chemistry without a basic understanding of the periodic table. The apparent relationship between teacher knowledge representation in chemistry and teachers' approach to teaching utilizing the periodic table highlights the necessity for more in-depth research on the examined topic.

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APPENDIX A

OBSERVATION GUIDE AND DATA PRESENTATION

Surname and initials	:	Teacher 1 (T1) and Teacher 2 (T2)
Subject specialisation	:	T1 -Physical sciences; T2-Chemistry
Years of experience in teaching	:	T1- 25 years; T2- 3 years
Qualification level	:	T1- Bed (FET)(HON): Natural Sciences T2- Bachelor of Chemistry
Years of experience in teaching grade 12	:	T1- 24 years T2- 1 years
Evaluator	:	Researcher

Background

Observation for teachers focused on how they utilise the periodic table when teaching chemical reactions and chemical bonding. This was done to reflect on how teachers use and/or fail to use the periodic table in their own contexts. The observation process however, only focused on how the teachers use the periodic table when teaching chemistry. The effectiveness of their method and teaching process was determined by the qualitative data. The data collection method was chosen on the bases of its potential to report accurate teachers practice in teaching chemistry without tempering with their everyday teaching process.

The observation process consisted of 5 days observation of teachers' use of the periodic table when teaching chemistry, specifically chemical reaction and chemical bonding. Two physical sciences teachers with different teaching background and experience took part in the study voluntarily. Activities observed during the observation was teaching methods used in the classroom, the use of the periodic table and the assessment methods.

Purpose

The purpose of the observation is to accurately capture teachers use and/or fail to use the periodic table in their own contexts and learners utility of the periodic table during the lesson.

Observations

Table 1: Teachers and learners observation.

OBSERVATION (OBS)	FEED BACK
For Learning and Assessment Activities	
OBS 100: Teaching method(s)	**Teacher 1 (T1)** ● Teacher Focused Method (TFM) **Teacher 2 (T2)** ● Teacher Focused Method (TFM) and Learner Centred Method (LCM)
OBS 101: Assessment method(s)	**Teacher 1 (T1) and Teacher 2 (T2)** Worksheets as assessment tool ● Question and answer ● Classwork ● Test
OBS 102: What information is given to learners about the periodic tale?	**Teacher 1 (T1)** ● The teacher does not refer learners to the periodic table. ● The assumption is that learners know how to use the periodic table in extracting molar mass. **Teacher 2 (T2)** ● The teacher does not use the periodic table during the lesson.
OBS 103: The topic, educational aims, objectives and expected learning outcomes of the lesson?	**Teacher 1 (T1) and Teacher 2 (T2)** **Topic**: Chemical bonding **Aims and general objectives** 1. Ionic bonding / electrovalent bonds ● understand and know how to illustrate ionic bonding, as the attraction between positive and negative ions after electrons have been transferred between atoms. 2. Molecules and covalent bonds ● understand and know how to illustrate covalent bonding as the sharing of electrons when atoms bind. ● understand inter and intra-molecular forces. 3. Giant covalent structures ● know the structures of graphite, diamond and silicon(IV) oxide. 4. Metallic bonding ● know about metallic bonding **Topic**: Chemical reactions **Aims and general objectives** 5. Writing and balancing equations ● know how to write word equations and balance simple equations
OBS 104: How the lesson expected to help learners learn?	**Teacher 1 (T1) and Teacher 2 (T2)** ● It helped learners understand chemical reactions by describing

	different changes in matter and understanding whether they are chemical or physical changes. ● Learners were able to learn to include examples of each type of change (e.g., ice melting and salt dissolving for physical changes; leaves changing color and wood burning for chemical changes).
OBS 105: How and from whom can learners get help if they need it?	● The teacher (T1 and T2)
OBS 106: What learning resources do teachers (T1 and T2) use to help learners do the activity and where/how they can get access to them?	● Worksheet ● Teachers (T1 and T2) made copies of most of the worksheets and distribute to the learners. ● Some of the worksheets were prescribed in the learner's textbook.
OBS 107: How the activity given by the teacher fits into any assessment for the subject, and if it is assessed, the marking criteria?	**Teacher 1 (T1) and Teacher 2 (T2)** ● The activities are prerequisites of the structure of the exam. ● The marking criteria were based on the marking guidelines (memorandum) of the assessment. ● For some worksheets, the teacher (T1 or T2) is solely responsible for marking them, and other worksheets, the teacher marks them together with the learners.
OBS 108: The relevance of the learning beyond meeting the assessment requirements, e.g. in future life, practice, etc.?	**Teacher 1 (T1)** ● The teacher used a general understanding of how the abstract knowledge learned in class can be applied in the real world. ● An example of the shortage of carbon dioxide was used by the teacher. **Teacher 2 (T2)** ● The teacher struggled to connect real-life applications of chemistry with abstract concepts.
OBS 109: How is the activity implemented?	● Learners are given worksheets to complete and the teacher (T1 or T2) workout the corrections afterward.
OBS 110: Nature of the activity and teaching approach	**Teacher 1 (T1)** ● Teacher Focused Method ● The activities had short questions that tested learners' declarative knowledge and long questions that tested learner reasoning using scientific principles. **Teacher 2 (T2)** ● Teacher-Focused Method (TFM) and Learner-Centred Method (LCM). ● The activities mostly constituted of short questions that tested learners' declarative knowledge.
OBS 111: Timing and location of the activity	● The teacher (T1 or T2) adhered to time allocation per activity.
OBS 112: How time is used during the activity?	**Teacher 1 (T1) and Teacher 2 (T2)** ● The time was used effectively with a question-and-answer approach.
OBS 113: Roles and responsibilities of the learners	● They asked questions during the lesson. ● They were able to follow the lesson and they attempted to correct some of the procedures followed by the teacher. ● The teacher forgot to answer some of the questions and one of the learners reminded the teacher.
OBS 114: Resources made available to learners e.g. special equipment, learning resources, software, etc.	**Teacher 1 (T1) and Teacher 2 (T2)** ● Only worksheets were made available to the learners.
OBS 115: Help available to learners.	● The teacher (T1 or T2) was resourceful and provided the necessary help needed by the learners.
OBS 116: How are the learners behaving?	● Well disciplined.
OBS 117: How are they undertaking the activity?	● Positively.
OBS 118: How are learners using the help and resources given?	● Learners struggled to use the resources provided to them by the teacher (T1 or T2).
OBS 119: How are learners interacting with the learning environment?	● The learners seemed to be adapted to the environment and they use every resources at their disposal effectively.
OBS 120: Do learners appear more motivated, engaged, or better prepared?	● Yes
OBS 121: How are the participants interacting?	● By asking questions and being part of finding solutions.
OBS 122: Is there dialogue?	● Yes there is between the teacher (T1 or T2) and learners. However the dialogue was limited because the teacher was dominant and gave learners limited participation.
OBS 123: Is the dialogue constructive for learning?	● Limited
OBS 124: Who is talking/listening?	**Teacher 1 (T1)** ● The teacher was talking and learners were listening. **Teacher 2 (T2)** ● The teacher sometimes gave learners chance to talk and she listened.
OBS 125: Is there evidence in the dialogue that learners are learning?	● Yes, because they were forming part of the solution to most part of the assessment.
OBS 126: How is feedback being given to learners ?	**Teacher 1 (T1) and Teacher 2 (T2)** ● Corrections of the assessment.

OBS 127: What is the evidence that learners have achieved expected learning outcomes?	• Achievement outcomes.
The periodic table (PT)	
OBS 128: How does the PT compare to the original design?	• There was no model or learning resources designed by the teacher (T1 or T2).
OBS 129: Does PT appear to be of good quality (visual, sound, contents, structure of contents)?	• The teacher (T1 or T2) and the learners used the periodic table in the textbooks. The structure of the content and visuals was of good quality.
OBS 130: How are learners introduced to the PT (verbal information, written information, demonstration, training etc)?	**Teacher 1 (T1) and Teacher 2 (T2)** • Written and verbal information
OBS 131: What information is given to learners about the PT?	**Teacher 1 (T1) and Teacher 2 (T2)** • Interpretation of atomic number and molar mass.
OBS 132: How will PT help learners learning?	**Teacher 1 (T1)** • The approached used by the teacher encouraged route learning when using the periodic table. **Teacher 2 (T2)** • The approach used by the teacher accommodated learner interactions with the periodic table as a tool, but limited in knowledge reconstruction using the tool as content.
OBS 133: How to access and use PT?	• Learners have the periodic table in their physical sciences text book. • They mostly use the periodic table when the teacher (T1 or T2) instructed them to use the tool or in an exam room writing chemistry test.
OBS 134: How are teachers and learners using PT?	**Teacher 1 (T1)** • The teachers seems not to be using the periodic table in class. **Teacher 2 (T2)** • The periodic was used as a referral source by both learners and the teacher.
OBS 135: What do they seem to find helpful in the periodic table?	**Teacher 1 (T1) and Teacher 2 (T2)** • The atomic mass and molar mass in the periodic table.
OBS 136: What do they (teachers and learners) have difficulty with?	• Interpreting and implementation of the periodic table.
OBS 137: How are they using PT to interact with other learners?	• Less interaction in the utility of the periodic table.

Table 2: Teacher conceptions of the periodic table.

The description of components constituting the conception	Conception
1. Concept [PT as content and tool] • Concepts are tools that "allow us to make sense of and organize the world…" Yee (2019, p.1258)	**Teacher 1 (T1)** • ***Concepts of PT as content*** The teacher classified periodic table content as separate knowledge from that of chemical bonding and chemical reaction. That is, the teacher's approach to teaching chemistry concepts had no link to periodic table knowledge as a baseline concept that links other chemistry concepts. For example, in the teaching of chemical equation representations, the concept was taught by the teacher without outlining the properties of the periodic table **[OBS 102]**. The use of the periodic table content when teaching other chemistry concepts was in various states of completeness, structure, validity, adequacy, and accuracy. For example, the method used by the teacher was mostly a teacher-centred method with less engagement in the content of the periodic table and more focused on route memory of chemistry concept **[OBS 100 and 132].** In the context of his teaching, only selected content such as identification of molar mass, atomic mass, and the name of the element as he characterized them, may to some extent allow him to make sense of and organize his chemistry teaching. Other content such as valence electron, the position of an element in the periodic, and factors of atom reactivity had less importance in his organization of learning **[OBS 131]**. • ***Concepts of PT as a tool*** The teacher approach offered less participation to learners and often chose to maintain control in the classroom rather than giving learners the opportunity to participate in the progression of the lesson. The use of the periodic table as a tool was mainly the identification of molar mass, atomic mass, and the name of the elements with less emphasis on "why" and "what" questions when extracting information from the periodic table. As a result, in the context of **T1** teaching, the periodic table in the learning environment carried less significance in the interpretation of chemical concepts and had no effect in the enhancement of learning. In the view of the teacher, mastery of chemical bonding and chemical reaction was more important than understanding the properties of the periodic table **[OBS 132]**.

	Teacher 2 (T2) • Concepts of PT as content The teacher assigns learning of the periodic table content to the mental task. She mostly relates the information that needs to be learned about the periodic table to learners. This means that **T1** sometimes relied on her capability to deliver content to promote critical thinking to learners and effective thought processing **[OBS 132]**. For example, her teaching approach had both teacher-centered method and Learner-centered. The teacher allowed learners to be involved in teaching, both teacher and learners at some extent, participated in the knowledge construction of chemical bonding and reaction that was reliant on periodic table properties. The content of the periodic table, in the context of **T2**, was crucial in the interpretation of chemical concepts **[OBS 100 & 132]**. • Concepts of PT as a tool In the context of the **T2** approach about the utility of the periodic table, teachers recognized learners' alternative ideas that are often significantly different and surprisingly difficult to change when teaching chemical processes as elements that affect conceptual change. As a result, **T2** often used questions and answers as an assessment method to identify some of the alternative ideas the learners hold about the periodic table and uses a teacher-centered method to assist learners to find new ideas of the periodic table that are plausible and fruitful **[OBS 110]**. Teacher use of the periodic table as a tool was limited. Her approach, however, identified the periodic table as a crucial element in the enhancement of learners' understanding of chemical concepts. This is evident in the **T2** approach. That is, she included some of the periodic table properties in her interpretation of chemical bonding and chemical reaction such as valence/valency electrons, the properties of an atom based on its position on the periodic table, electronegativity and the reaction capability of an atom **[OBS 132]**.
2. Meaning **[**What the use of the periodic table means in the teaching of chemical bonding and chemical **reactions]** i.e., Content to be taught **about** the periodic table, the intended **object** of the teaching, that which the teacher **intends the learner to learn** (Hewson & Hewson, 1989).	**T1** The teacher's teaching method was more Teacher Focused and less Learner Focused and did not aid learners' own meaning constructions through controlled activities. The periodic table was referred to as a source of reference. For example, use the periodic table as a reference tool for names of elements, atomic number, atomic mass, and electronegativity of an element. Learning the periodic table, on the other hand, is a chemical idea that must be learned first. As a result, it can't be used as a reference tool since it includes complex knowledge and interpretations that serve as the foundation for most, if not all, chemical topics **[OBS 100 & 132-134]**. **T2** Teacher's interpretations of periodic table ideas, words, and phenomena were mostly correct, with consistent meanings and applications **[OBS 102]**.
3. Belief i.e., attitudes, values, propositions, preferences Beliefs can influence peoples' thoughts and behaviour about something e.g., active learning.	**T1** The notions connected with using the periodic table as a teaching tool usually conflict with teachers' views. That is, the aspects of their belief system operate against their chemistry teaching technique. For example, despite knowing how important it is to understand the periodic table in order to grasp chemistry concepts, the instructor continues to miss or fail to apply periodic table knowledge into chemical processes **[OBS 102]**. **T2** Teachers' opinions were influenced by factors such as attitude and social adaption in her depiction of periodic table knowledge. As a result, rather of incorporating the periodic table information into their normal instruction, the teacher abdicates her responsibilities to teach it. In actuality, the instructor separates himself from the students and blames the periodic table for the students' lack of focus **[OBS 108]**.
4. Nature of science Any statement which refers to the content to be taught about the periodic table, the intended object of the teaching, that which the teacher intends the learner to learn. • The natural phenomena which are investigated. • The method of investigation. • The explanation of phenomena in terms of concepts. • Prediction, explanation, application and problem solving. Hewson and Hewson (1988)	**T1** Teacher Focused Method (TFM) was mostly used in day to day teaching of chemical bonding and chemical reaction if not in every lesson. This entails that the teacher mostly presented previously investigated results rather than engaging learners in finding the solutions **[OBS 100]**. Chemical bonding and chemical reactions were the investigated phenomena **[OBS 103]**. The teacher's explanation of scientific concepts was largely dominated by explicit explanation with little involvement of learners in the process. Learners were engaged by the question-and-answer method that was sometimes used by the teacher. The periodic table was only used as the

	referral tool for numbers such as atomic number, mass number, group number, electronegativity, and molar mass. This entails that the lessons were mostly on the explanation of concepts and offered less opportunity for prediction and application of knowledge. Learners were given problems to solve based on the content taught **[OBS 102]**. **T2** TFM was used **[OBS 100]**. The teacher's explanation was mostly interactive. The teacher engaged the learners throughout the process of teaching and learning chemical bond and chemical reactions. The utility of the periodic table was not encouraged and the knowledge of the periodic table was not incorporated in the teaching of chemical bonding and reactions. Predictions, explanations and problem solving were part of the lessons **[OBS 102, OBS 121 and 122]**.
5. Teacher characteristics Any statement which refers to those characteristics which are likely to influence how and what a person teaches the periodic table. ● The persons knowledge, both cognitive and affective (aspects of knowledge or knowing which seems to bring forth particular emotions), which may include knowledge of the content, the periodic table, goals and personal conception of knowledge. ● The personal approach to the task of teaching using the periodic table which may include motivation (intrinsic and extrinsic), behaviour and attitude. Hewson and Hewson (1988)	**T1** The teacher possess quality knowledge of the periodic table and its applications. However the teacher, seems to assume that learners have similar knowledge of the periodic table **[OBS 108]**. Excellent knowledge of chemical bonding and reactions. The teacher effectively connected the abstract concepts with more general understanding of the learners **[OBS 108]**. The goal of the teacher was to teach the chemical bonding and reactions effectively without having to teach the content of the periodic table **[OBS 131]**. The teacher in general is motivated to teach science, and so are the learners motivated to learn. But the teacher however, is not motivated to teach the periodic table or include the periodic table as part of the everyday lesson. The content of the periodic table seems to be less relevant to other chemistry concepts and is used as referral tool. This is due to the perceptions that learners can do well in chemistry without having to be reminded or taught the periodic table content **[OBS 128-137]**. **T2** The approach was less teacher focus and gave learners a chance to express their knowledge and also gave them the opportunity to interact with the periodic table. However, the interaction was minimal **[OBS 113** and **OBS 121-125]**.
6. Rational for instruction Any statement which refers to the reasons which a person may give for using a particular instructional method to teach the periodic table. ● The nature of the content. ● Evaluation of outcomes of instruction. ● The context of instruction, whether formal or informal. ● The teacher personal expectations, concerns, capabilities and knowledge. Hewson and Hewson (1988)	**T1** The content appeared to a bit challenging to learners since it required the integration of concepts more special the interpretation of the periodic table. This was due to teachers and learners less interaction with the periodic table [**OBS 136 and OBS 137]**. Worksheets where used as tools of assessment and method of assessment was mostly question and answer and corrections of the work given. The setting of the teaching environment was formal including the assessment **[OBS 101]**. Teacher expectation in general was to nature knowledge restructuring in chemical bonding and reactions. That is different representations of matter and relating abstract concept to their everyday knowledge. The teacher showed little concern in his approach of teaching and seems to place more confidence in his capability to teach and in the assessment given to learners **[OBS 104 and OBS 105-115]**. **T2** The teacher approach placed more concern in the inclusion of learners though out the lesson and place less trust in her capability to teach but rather more trust in learner capability to construct their own knowledge in the process **[OBS 108]**.
7. Preferred instructional technique Any statement which refers to the strategies, techniques, methods, and practices which the person would use an be effective in the utility of the periodic table. ● Planning, and preparation of instruction and activities. ● The nature of teacher-learner interaction. ● The type of instructional technique. Hewson and Hewson (1988)	**T1** The teacher planning, preparation of instruction, and activities had no inclusion of the content of the periodic table **[OBS 129]**. Teacher and learner interaction was very positive and interactive **[OBS 119-124]**. TFM was used **[OBS 100]** **T2** Preference of instructional technique was TFM **[OBS 100]**.