

Innovative Ways of Teaching Periodic Table at Secondary Stage

Dr. Ravijot Sandhu

Abstract

Periodic Table (Chemistry) of the elements has found its place in the syllabus of science at secondary stage in India. It has been observed across the years that students find Periodic Table and the other concepts related to it difficult to understand. Review of literature also shows that Periodic Table is considered difficult by students across the globe. Students consider this topic dry and abstract. Therefore, it becomes challenging for teachers and teacher educators to transact this abstract topic to students in an interesting way. This research paper focuses on the innovative ways of teaching-learning of Periodic Table which has resulted in enhancing learning curve and interest quotient among students.

Key Words: Innovative ways, Modern Periodic Table, Secondary Stage, Visually Impaired Students.

Introduction

In Chemistry, the Periodic Table of elements has been introduced at the secondary level of school education and is considered the the most fundamental topic. It is one of the most important tools through which various concepts of chemistry can easily be understood by learners, such as, idea of electronic configuration, atomic size, chemical bonding, metallic and non-metallic nature of elements, electronegativity etc. It provides information about elements and how these elements are related to one another. The Periodic Table can be used to predict the properties of even those elements, which are yet to be discovered. Therefore, it becomes imperative for students to understand Periodic Table meticulously, so that they can discuss the properties of an element just by looking at it.

The research studies have shown that teachers find various topics given at secondary level difficult to teach (Mokiwa 2007; Mehrotra & Koul 2012). Researches have also shown that many teachers find Periodic Table difficult to transact. Roddy, Knight Phares, 2003; Matthias Bierenstiel, Kathy Snow, (2019) have also reported that 'Periodicity is an abstract concept', 'Periodic patterns are complex' and students do not have sufficient prior knowledge of the elements and their properties.

While teaching students of Grade X for the last 27 years, Researcher has observed that students face difficulty in learning the modern Periodic Table. Teachers also consider this topic difficult to transact to make students understand the grouping together of 118 elements (author's personal experience). In the beginning of Researcher's career, she used to transact this topic using large size coloured wall-chart of Periodic Table in the classroom. This was probably because she was trained in her pre-service professional training to teach this topic in this manner only. Over the years, Researcher realised that students feel this topic as a burden and stressful.

Dr. Ravijot Sandhu, PGT-Chemistry, Navyug School, NDMC-Peshwa Road, New Delhi.

While taking feedback from students about this topic, this was their response:

Students: *We are not finding this concept at all interesting. Some students said that they remember symbols and atomic number of elements of the Periodic Table by heart, but forget everything during exams.*

The Researcher also enquired about the experiences of her fellow colleagues about this topic. Following were the responses:

Teacher 1: *Yes! Students are not able to remember about the elements. Ohhh ...I simply tell them to keep on repeating about the elements several times aloud. In this way only they are able to remember the elements.*

Teacher 2: *It was difficult for students even to remember the atomic numbers of the elements, as a result they would make mistakes while writing electronic configuration of elements.*

Teacher 3: *I have to struggle to make students visualise the abstract concept that atomic size of elements increases as we go down the group in a Periodic Table.*

Similarly, many more teachers showed equal discomfort in teaching this topic.

Researcher also tried to make this topic interesting using ICT, showing students online lessons and videos to strengthen this topic. It helped Researcher a bit but due to lack of internet facility, it was and is a big challenge for some students in a developing country like India. Sometimes internet facility is available, but speed of network becomes an issue.

Literature shows that very limited research studies have been done on teaching-learning strategies of Periodic Table. Considering this as a universal problem across the globe; Researcher developed, and also used various innovative teaching-learning strategies to make this topic interesting. The Researcher focused on the following research questions:

Do innovative ways of teaching Periodic Table enhance learning and to what extent than traditional ways?

Do innovative ways of teaching-learning of Periodic Table generate interest among learners of secondary stage?

Methodology and Design of the Study

Sampling and Tools

The study was conducted in the Government Schools of Delhi, India with Grade X students. Around 118 students participated in this study. The Researcher taught the Periodic Table to students through traditional methods using coloured wall mounted 2 D Periodic Table, textbooks, chalk and talk method etc. To access the conceptual understanding of students regarding the topic, the Researcher gave them a Pre-test in the form of questions and told them not to disclose their names on the Pre-test so that they could answer the questions freely and honestly. The focus was on the learning and not on the measurement of learning. Since the study was aimed at seeking answers to specific questions, the Researcher used the purposive (non- probability) technique of sampling.

Pre-test

Five questions were given in the Pre-test. In each question, students were asked to answer the question with reason(s). The responses of students are shown in Table-1. The Researcher has reported the original responses of the students without making any modifications. Similar responses given by the students are grouped together.

Table 1 Students Responses to Questions in the Pre-Test			
SL NO.	QUESTIONS	RESPONSES	REASONS GIVEN
1	Which of the given elements A, B, C, D, E with atomic number 2, 3, 7, 10, 30 respectively belong to the same period?	• 2,3,7 by 56 students • 10,30 by 15 students • 3,7,10 by 10 students • 3,7,10 by 28 students but with wrong reason • 9 did not respond	• Don't know reason, have memorized • Lower atomic numbers belong to same period • Higher atomic numbers belong to same period
2	Write the symbols of Sodium, Aluminium, Phosphorus and Chlorine.	• Na, Al, P by 91 students • NA, AL, P by 4 students • S, A. P, C by 14 students • 9 students did not respond	• Letter in the beginning of word is the symbol • Each element has unique symbol • Symbols are taken from the names of elements in Latin, German or Greek.
3	Which one amongst the elements H, Na, K has bigger atomic size?	• H by 8 students • Same size by 60 students • K by 41 students • 9 did not respond	• These elements belong to same group, so size is same • H has special place as it has bigger size. • K is at the bottom, the size is big
4	Which is the outermost shell for elements of period 3?	• V shell by 51 students • M shell by 46 students with wrong reason. • N shell by 12 students • 9 did not respond	• Valence shell is the outermost shell named as V. • 3 shells are there in period 3. • K, L or M any letter can represent any shell.
5	Where would you locate the element with electronic configuration 2, 8 in the modern Periodic Table?	• 2nd Group by 71 students • 8th Group by 15 students • 18th Group by 23 students • 9 did not respond	• Elements with two shells will be placed in 2nd Group. • Element with electronic configuration 2, 8 has octet configuration so must be an inter gas which is placed in Group 18. • It has 8 valence electrons so belongs to 8th Group.

Analysis of Responses and Discussion

All the five questions were answered by students, only 9 students did not respond to any of the questions given in the Pre-test.

Question 1 was answered correctly by 38 students out of which 28 gave wrong reason. Some also admitted that they have simply memorised the concept.

Question 2 was answered correctly by 91 students and most of them had given correct reason, whereas 18 answered it incorrectly. This was made clear to them that the first letter of a symbol is always capital (Upper case) and the second letter as a small letter (lower case). Also, symbols of some elements are formed from the first letter of the name and a letter appearing later in the name, so Chlorine is Cl. Other symbols have been taken from the names of elements in Latin, German or Greek, so Sodium is Na from Natrium and Potassium is K from Kalium.

Question 3 was answered correctly by only 41 students. The Researcher observed the concept of increase in number of shells with increase in atomic number on going down the group needed to be strengthened using some innovative ways.

Question 4 was correctly answered by 46 students but none of them gave correct reason that 3rd period has 3 shells K, L, M, therefore, M is the outermost shell. The reasons given were quite vague. They could not comprehend that innermost shell is K and so outermost will be M. 51 students answered incorrectly, however they know that the valence shell is the outermost shell but named it incorrectly as V after valence shell.

Question 5 was answered correctly by only 23 students with correct reasoning that elements with electronic configuration 2, 8 has octet configuration, so must be an inert gas which is placed in Group 18. 2nd Group was answered by 71 students which was incorrect and Researcher observed that there was a lot of misconception as they had cited wrong reason that elements with two shells will be placed in 2nd Group. 15 students gave incorrect answer citing wrong reason that it was placed in 8th group as it had 8 valence electrons.

Interventions

As was evident from the Pre-test responses that there were many reasons for students facing difficulty in learning periodicity. Also, a conversation between two students (given in box) forced the Researcher to give some innovative interventions.

Jatanbhola is a visually impaired child - Madam, how to learn this huge table and how are elements arranged here?

Arun is a sighted student—Jatanbhola, you leave this topic...It's not for you to understand. This conversation between two students forced me to think of a way where my visually challenged students could also understand Periodic Table easily.

The Researcher took it as a challenge and during intervention following innovative methods were used:

- (i.) Relating roll numbers to atomic numbers
- (ii.) Formation of human Periodic Table in playground
- (iii.) Designing and creating 3 D Model of Periodic Table

And the journey began...

(1) Relating Roll Number with Atomic Number and Name of the Element

First challenge was to find an easy way to recall the elements and their atomic numbers correctly.

In classroom usually students are allotted roll numbers. So, each roll number was allotted the name of the element. For example, Roll Number 1 of the class was called Hydrogen, Roll Number 2 of the class was called Helium..... Roll Number 11 of the class became Sodium and so on..... This innovative way of relating roll numbers to the atomic numbers of the elements was something students easily adopted.

ROLL NUMBER = ATOMIC NO = NAME OF THE ELEMENT

This innovative way worked and within a month entire class became well versed with atomic numbers and names of elements till atomic number 40. the Most of times students used to address each other with the names of the elements. The new names given to the students almost became their 'Nick' names. Let us have a peep into the classroom during Roll Call-

Conversation during Class Attendance

Teacher: Class monitor, please tell me who all are absent today?

Class Monitor -Madam, today Oxygen, Sodium and Zinc are absent.

Teacher - Marked roll numbers 8, 11 and 30 absent in the attendance register.

This innovative method showed that students were taking interest unconsciously remembering the names of Transition Elements, even though these elements are not part of the syllabus at secondary level. Students were also motivated to design and develop 'Element I-Card' with all the related information of the element written on it along the symbol of the element. They were encouraged to wear 'Element I-Card' during science class. This innovative method helped the Researcher because unconsciously students were gathering information about elements and they were interested in knowing more; how the particular element was discovered and its importance in daily life.

(ii) Creating of Human Periodic Table on Ground

During teaching-learning process sometimes students were motivated to assemble in playground or any open space and encouraged to arrange in the form of a Periodic Table (Figure 1). Researcher observed that engagement of students in small groups (Groups 1,2,13,14,15,16,17,18) and then joining together to form a network of larger group not only helped them in understanding the Periodic Table but also inculcated values of cooperation, extending help to each other and communication skills. It was also observed that some students were hesitant in participating in such activities and were also unable to locate their position. The



Figure 1

Researcher assisted them by discussing their atomic numbers and their electronic configurations, number of shells the element has, in detail. The students were also encouraged to ask questions. Some students exchanged their 'Element I Card' and their positions to stand according to their height. On asking -why have they exchanged their positions? The answer surprised the Researcher. They said that the taller students meant larger atomic size and the one in front (shorter in height) represented element with smaller atomic size (Figure 2). This deliberate attempt showed that students were enjoying and showing interest in understanding the concepts given in Periodic Table.



Figure 2

Another innovative way turned into a game, where the Researcher would call out the Group Number and students of that group would march out or when Researcher would say Period 3 Group 2; Magnesium would run up to the Researcher to get a score on the Score Board. Sometimes students themselves coined new ideas; they had fun when a boy and girl ran together up to the Researcher to form NaCl !

This became a very interesting, well tried and tested way of transacting atomic numbers, names of elements, groups and periods while teaching 'Periodic Classification of Elements' to Class X students. The research study has also shown that the students' perception of the games became more favorable than for other class tasks used in the control group for teaching the Periodic Table of Elements at the High School Level (Antonio Joaquín Franco- Mariscal et.al2015)

(iii) Designing and developing 3-D Model of Periodic Table

Researcher planned to design and develop 3-D model by involving students, with a conscious attempt to use locally available eco-friendly material such as clay/ soil, broom sticks/twigs.

The class was divided into 6-7 groups. Each group was motivated to first prepare 18 'Group Sticks'. This way students learnt Modern Periodic Table in parts. On day one, students made small beads/balls of clay/ mud and coloured them. In each bead/ ball of clay atomic mass, atomic number and symbol of element was written. Care was taken to make same- coloured beads/ rounds belonging to one Group/Family. Students' experiences, previous knowledge, active participation, involvement and accommodating others point of view in developing and colouring the beads ensued learning from each other.

For example - Group 1 stick had H, Li, Na, K, Rb, Cs, Fr and care was taken to keep the size of the clay ball of Sodium smaller than Potassium than Rubidium and so on (Figure 3). Making one 'Group Stick' at a time helped them to digest the information more quickly. The Periodic Table was thus colour coded according to the types of elements. Students thus formed 18 sticks with balls of clay representing the elements belonging

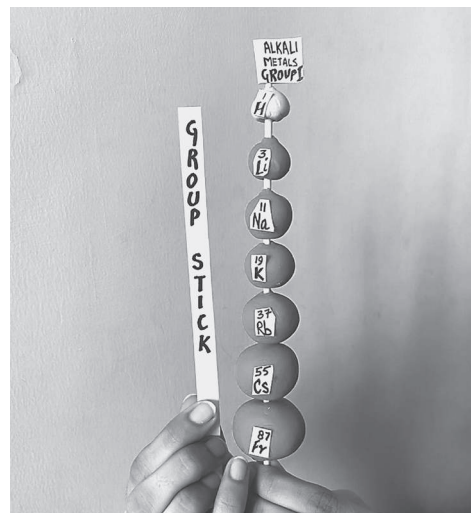


Figure 3

to that group. Different Group Sticks were placed vertically on used cardboard boxes. Thus, slowly six to seven 3-D Periodic Tables were ready. The main attraction was that these Group Sticks were detachable and easy to refer during teaching-learning process. The students were excited to remove chlorine (in this case ball of clay/bead) and compare its size with Fluorine and then again fix it back on its appropriate position. This way they could easily visualise the increase in size of the elements on going down the group. This type of model was particularly useful for visually impaired students who were able to feel all the elements of the Group and compare its varying sizes down the group.

In two strings, element beads of Lanthanides and Actinides series were also made to complete the Modern Period Table (Figure 4).

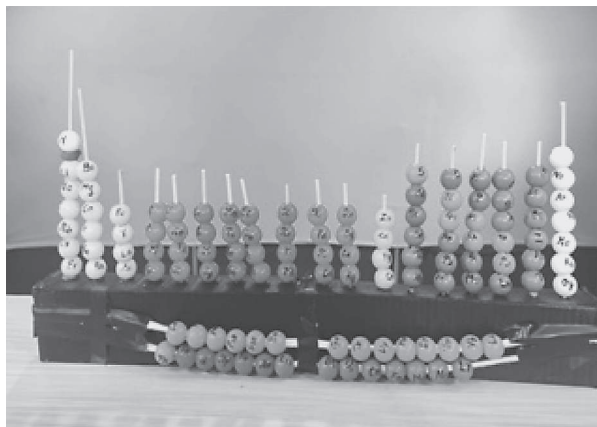


Figure 4

As an assessment, extra clay balls/ beads were kept aside made by one of the teams and students were encouraged to string 1st, 2nd and 3rd Period on sticks placed horizontally. The atomic radius decreases in moving from left to right along a period. This is due to an increase in the nuclear charge which tends to pull the electrons closer to the nucleus and reduces the size of the atom (NCERT 2007). For example-on a horizontal stick in 3rd Period we have atoms Na, Mg, Al, Si, P, S, Cl, Ar (Figure 5). Thus, care was taken to keep the clay ball size of Chlorine smaller than Sodium.

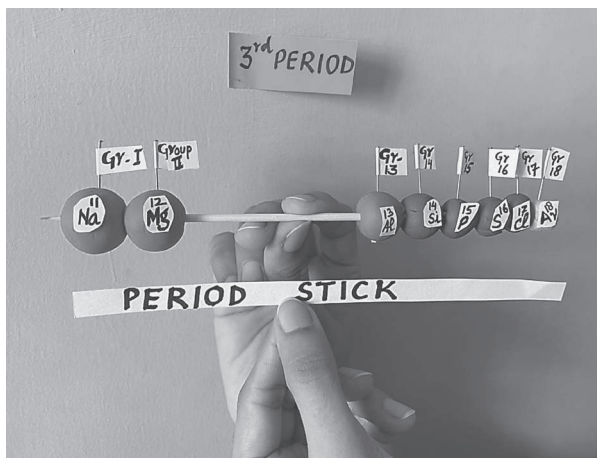


Figure 5

The Researcher was assessing the students in a constructive and positive manner, thereby preserving the confidence and self-image of the students. Since diversity is a part of what we call 'normal', so the approach was as per the students' capabilities, interests, motivations and experiences that are unique and individual (NCERT 2013). During this part of the study, the researcher also facilitated discussion with the students, responded to their queries, appreciated their ideas and thinking in developing a better understanding. Various research studies have also shown that how activity-based teaching and learning leads to improved learning outcomes by students. (Khan, Muhammad Ahmed, Et.al 2012, Koul 2014). Children with average to low verbal ability and with little previous knowledge learn more through project-based learning. (Mergendoller.J &Markham.T(2006); Mioduser.D & Betzer. Nadav (2008); Koul & Wazalwar, 2014).

After intervention, a Post-test was given to the students to ascertain whether there was any improvement in their understanding and competency on the topic 'Modern Periodic Table.'

Post-test

Five questions were given in the Post-test to the students and were asked to answer with reasoning. The responses of the students are provided in the Table-2. The Researcher has reported the original responses of the students without making any modifications.

Table 2 Students' responses to questions in the Post-test			
SL. NO.	QUESTIONS	RESPONSES	REASONS GIVEN
1	Which of the given elements A, B, C, D and E with atomic number 10,11,15,18 and 30 respectively belong to the same period?	• 11,15,18 by 113 students • 10,11,15,18 by 5 students	• Third period of Modern Periodic Table contains elements with 11,15 and 18 atomic numbers. • 10 to 18 are in same period.
2	Where would you locate the element with electronic configuration 2,8,8 in the modern Periodic Table?	• 18th Group by 116 students • 8 th Group by 3 students	• Element with electronic configuration 2, 8, 8 has octet configuration so must be an inert gas which is placed in Group 18. • It has 8 valence electrons so belongs to 8th Group.
3	Which one amongst the elements Na, Mg, K, Ca has the largest atomic radii?	• K by 118 students.	• Top to bottom in a group atomic radius increases, whereas in a period from left to right it decreases. So, K will be largest in size.
4	Which amongst the elements Na, F, Mg and Al does not lose an electron easily?	• F by 107 students • Na by 11 students	• Metals can easily lose electrons and form electropositive ions whereas Non-metals gain electrons. F is a non-metal. • Na, Al Mg are metals and can lose electrons easily.
5	Which one amongst the elements -Na, Al, Si, P exhibit maximum number of valence electrons?	• P by 108 students • Al by 5 students • P by 5 students with wrong reason	• On moving from left to right in a period, number of valence electrons also increases. • P is on right hand side so has more valence electrons.

Analysis of Responses and Discussion

All five questions were answered by all the students. Question 1 was answered correctly by 113 students, 5 students were still confused. Since the students were working in groups, they helped each other in understanding this concept. The 'Period Sticks' of 2nd and 3rd periods (placed horizontally) were once again shown, and students were encouraged to take out all the element beads and rearrange them accordingly.

Question 2 was answered correctly by 116 students. Only 3 students answered incorrectly. The students were told to relate position in Groups to the valence electrons and electronic configuration of the elements. The students who understood better were motivated to explain to their peers. This helped the Researcher to a certain extent.

Question 3 was answered correctly by all the students. Na and Mg belong to the same period whereas Na and K are in the same group. Top to bottom in a group atomic radius increases, whereas in a period from left to right it decreases. So, K is largest in size. They said that they had made the clay balls of increasing size and put them in 'Group Stick' in order of increasing order. On asking, they said that it was easy to remember that on top we kept smaller balls and on the lower end of the vertical stick we had kept the bigger balls. They further said that on 'Horizontal Period Stick' left hand side had bigger balls and on moving towards right hand side, the size decreased. This they supported with correct reasoning.

Question 4 was answered correctly by 107 students with correct reasons. This question was thought provoking and it was encouraging to note that they had correctly argued that metals lose electrons and form electropositive ions. During discussion they had chosen Fluorine as the correct answer. This was supported by the reasoning that non-metals gain electrons and Fluorine was the only non-metal amongst them. On probing further, they pointed out to the structure of Sodium and said that amongst Na, Mg and Al; Sodium will lose electron most easily. This proved that students had understood the concept well. It is also important to know that sometimes students learn better by making errors and mistakes as it is an integral part of the learning process. Participation of all the learners in various aspects of teaching-learning should be ensured (NCERT 2013). 11 students who could not answer correctly, were constantly listening to their friends and through collaborative learning, gap was filled.

Question 5 was correctly answered by 113 students with correct reason; that on going from left to right hand side, number of valence electrons also increases. On probing they registered that as the group number increases, number of valence electrons also increases. Five students were still confused and could not relate the increase in group number to increase in the valence electrons.

Findings

On analysing the Pre-test (Table-1) and the post- test (Table- 2) responses, it was found that teaching Modern Periodic Table through innovative ways had a positive impact on students. Not only learning through innovative ways helped students to learn better but they were also given freedom to explore, inquire and discuss amongst themselves. All 118 students responded to all the questions in the Post-test. On comparing Pre-test and Post-test responses, it showed that there was improvement in both the conceptual understanding and generating interest amongst students. It is a myth that teaching a topic through activities takes longer time to finish the prescribed syllabus. As a Researcher, it was observed that if we use innovative methods, it becomes easier to transact any concept and students also understand concept without stress. Another interesting finding was that Group Learning brought improvement in self-reliability, independence in dealing with others, ability to make decisions, become considerate and helpful towards others. In the group, students jointly negotiated their understanding, planned tasks, explained things to each other, shared ideas and coordinated actions.

The following are the responses of students working in groups (in local language; translated by Researcher). These are presented here without any modification:

- (i) “I love to play with clay and soil/ dough. It is so much fun. But my mother scolds me if I make the place dirty. Now I will tell her I am making balls or beads to represent elements or electrons”.
- (ii) “Colouring the clay balls was so much fun. I thought science was all about theory, notebooks and textbooks. It seemed as if I was in Art Class”.
- (iii) “Once the topic was complete in the class and we were asked to write our learning and experiences in our portfolio, we were bound to revisit concepts of that topic. While putting our thoughts in portfolio we thoroughly understood the concepts given in that topic while recalling”.
- (iv) “While preparing the 3-D model of Periodic Table, we felt so confident making our own Periodic Table”.
- (v) “My roll number is 8 and friends call me Oxygen. All living beings depend on me”.
- (vi) “Making Human Chain to form Groups is so easy to remember who all are there in my family”.

Conclusion

It was observed by the Researcher that when Modern Periodic Table was taught through traditional method, students neither showed high level of interest nor scored high. Responses of the Post-test showed that while teaching Modern Periodic Table through innovative methods, students were enthusiastic to learn and showed keen interest in the preparation of 3-D Model and shared different views of preparing more such models and science games. This was possible only when a culture of excitement, curiosity, open thinking and exploration was created.

It was observed that the students who participated in this study attempted all the questions related to the Modern Periodic Table and gave correct responses in the term end exam as well, which established that there was retention of the concepts taught through innovative ways.

An important implication of the study is that teaching-learning of Modern Periodic Table by innovative methods resulted in high level of achievement in terms of scores and deep understanding of concepts. There are evidence, suggesting that the classroom participation increases, so there should be inherent flexibility in the learning approaches to provide ample scope to address learning needs of a diverse group of learners in a science class. An important implication of the study is that curriculum planners can take a hint from the curious questions/ responses of the learners and design innovative models/games on the science topics.

In an increasingly complex and changing pedagogical context, it is vital for teachers to move away from traditional way of teaching and embrace pedagogical shift in science education by providing more opportunities to students for scientific exploration and making it inclusive and meaningful. Every topic demands different treatment so teacher should use a variety of approaches and strategies that ensure active

participation of learners, collaboration among learners and recognition of their knowledge and previous personal experiences.

References

- Antonio Joaquín Franco-Mariscal, José María Oliva-Martínez, and M. L. Almoraima Gil. (2015). Students' Perceptions about the Use of Educational Games as a Tool for Teaching the Periodic Table of Elements at the High School Level, *J. Chem. Educ.*, 92, 2, 278–285. <https://doi.org/10.1021/ed4003578>, The American Chemical Society and Division of Chemical Education, Inc.
- Khan, Muhammad Ahmed, Et.al 2012) Impact of activity-based teaching on students' academic achievements in physics at secondary level. *Academic Research International* 3(1):146-156
- Koul, A. (2007). Straight from the professional development classroom: A practical experience, *Teaching of Science, The Journal of Australian Science Teachers' Association*, Volume 63, Number 1.
- Koul, A. & Wazalwar, A. K. (2014). Collaborative project in science and mathematics at middle school level- A case study. *Journal of Science and Mathematics Education in Southeast Asia*, 37(2), 178–197.
- Koul, A. (2014). Impact of innovative approaches in teaching-learning of science on rural students at middle school level. *Asia-Pacific Forum on Science Learning-Teaching*, 15(2), Article 11.
- Matthias Bierenstiel, Kathy Snow. (2019). Periodic Universe: A Teaching Model for Understanding the Periodic Table of the Elements. *Journal of Chemical Education*, 96 (7), 1367-1376.
- Mehrotra, A., & Koul, A. (2012). Is Teaching–Learning of Mole Concept Difficult? *School Science- A Quarterly Journal*, 50 (2) 21-33. National Council of Educational Research and Training, New Delhi, India.
- Mergendoller, J. & Markham, T. (2006). Pervasive management of project based learning: Teachers as guides and facilitators- (PBL) Project- and Problem-Based Learning
- Mioduser, D. & Betzer, Nadav (2008) The contribution of Project-based-learning to high-achievers' acquisition of technological knowledge and skills *International Journal of Technology and Design Education*, Volume 18, 59–77(2008) Metrics
- Mokiwa, H. O. (2007) Reflections on teaching Periodic Table concepts: A case study of selected school in South Africa. HO Mokiwa, *Eurasia Journal of Mathematics, Science and Technology Education* 13 (6, 2007, Citations: 7)
- National Council of Educational Research and Training. (2013). *Pedagogy of Science, Textbook for B Ed. Students*. New Delhi, India.
- National Council of Educational Research and Training. (2006). *Textbook in Science for Class IX*, New Delhi, India
- National Council of Educational Research and Training. (2006). *Textbook in Science for Class X*, New Delhi, India
- Roddy, Knight Phares, (2003) "High school chemistry students' learning of the elements, structure, and periodicity of the Periodic Table: Contributions of inquiry-based activities and exemplary graphics". *LSU Doctoral Dissertations*. 2431.