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# Misconceptions in ‘Shape of Molecule’: Evidence from 9th grade science students

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**Students commonly develop alternative ideas about topics in science. According to constructivist view of learning, students’ alternative conceptions and misconceptions about the process of developing new knowledge should be highlighted. Remedy can be undertaken through conceptual change approach. In order to understand what factors causes 9th grade students to make mistakes in various sub concepts of shape of molecule, qualitative research design was followed. Misconceptions of the students about shape of the molecule were identified and analyzed. Accordingly, plan of action was framed for tackling each of the hard spots found among students. Lack of content information, previous knowledge, instructional approaches, process of assessment, cognitive and meta-cognitive strategies were attributed towards the cause of misconceptions.**

**Key words:** Misconception, shape of molecule, constructivism.

## INTRODUCTION

The system of teaching and learning needs to go beyond the cognitive domain. It should be seen as a tool for diagnosis and further learning. A shift from testing competencies can reduce rote learning. The focus of questions should move to genuine applications from mere ‘plug-in-type’ problems. National Curriculum Framework (NCERT, 2005) has a principle which makes a departure from the legacy of bookish learning, discourages rote learning and the protection of sharp boundaries between different subject areas. Position paper of National Focus Group on Curriculum, Syllabus and Textbooks (NCERT, 2006) remarked that ‘the children should be allowed to think and the teachers should be allowed to teach as they consider fit’. Thus, it should inevitably imply core content. Core content is meant only to provide either ‘enrichment for the talented’ or ‘remedial inputs for the backward’. The point being deliberated here is the development of reflective teaching practice which is a necessary condition for learning from one’s own experience.

### Science learning

Research on science education has shared the commitment of constructivism in relation to classroom learning. Constructivist approach is an effective learning tool which has significant effect on the achievement in science concepts among all psychological groups of students. It helps in achieving meaningful learning in

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science concepts among grade 9th students (Adak, 2017). The basis of constructivism is to view learning as an intensive process which by necessity occurs in a small group. Knowledge is not transmitted rather it is actively built up by the learner. Knowledge is not something that is delivered to the students but something that emerges from active dialogue among those who seek to understand and apply concepts and techniques. The learners have to make sense of new knowledge in terms of their existing knowledge. Therefore, well-designed practical activities that challenge learners' prior conceptions are required. It will portray the knowledge construction process by learners' experience into scientific discourses. Learners enact their beliefs, identities and activities by doing science (Roth, 2005). Learning science involves scientific ways of knowing. Scientific entities and ideas are validated and communicated through empirical inquiry. Thus, learning science is a form of meaningful understanding through organization of knowledge at an individual level. From this perspective, it is understood that scientific knowledge and understandings are constructed socially when individuals engage in talk and activity about shared problems. Meaning making is thus a dialogic process and hence learning science is seen as the process by which individuals are involved in the activities of culture. This is an important point for science learning.

## Challenges of science learning

Many complex topics in science demands intuitive thinking which may challenge the students (for example, the change of seasons). Intuitive thinking is obvious but this creates an encounter for teaching and learning. Hence, the significant relationship between the basic science process skills and misconceptions is detected. In a study on importance of concept teaching which is essential for active learning, it was found that concept teaching is especially important in eliminating misconceptions (Servet, 2018). A student who merely answers to end-of chapter questions does not perform better than students who participated in an unrelated activity. When answers are discussed, the teacher is free to intervene and that leads to spot-on student's thinking. Without teacher probing, it is doubtful that students will perform better than those who simply write answers to questions. It implies that attention should be given to give right kind of instruction when students encounter intuitive concepts.

It is important to shape the classroom. The potential for grouping of children of different age and level for certain activities should be considered. A diverse mix of learners with varied learning experiences and levels helps in enabling the process of peer learning. Group learning develops student's positive attitude to remove barriers that may adversely affect the success in social interaction (Karali and Aydemir, 2018). Actual learning happens only in the children's mind and depends totally on what has been learnt earlier. Therefore, the re-interpretation of the content, methods, materials are completely within the sphere of practical decisions to be made by the teacher.

Chemistry is a conceptual subject. When concepts are concrete, that is students are able to see and can manipulate or can be directly observable then understanding will be easy. But when concepts are abstract (for example atoms, molecules, ionic bond, covalent bond) students may ask questions. Thus, teaching such topics is a challenge to make the students learn; one of the widely recognized issue is that students develop alternative ideas about topics in science. The real challenge on the part of the teacher is not to distribute knowledge rather to make a shift in their thinking towards conceptual understandings. Research documented the necessity of applying effective new teaching methods in courses in order to eliminate misconceptions. The textbooks which have an important place in teaching environment should be developed in such a way that it prevents building misconceptions and eliminates misconceptions that have been taught (Koksal, 2006). These alternative ideas are labelled as alternative conceptions. These are commonly known as misconceptions (Eryilmaz, 2002).

Alternative conceptions arise due to previous knowledge. How the learners are exposed to variety of contacts with the society and community is one of the main concerns. The personal experience is gained through exposure with the society, interaction with people, teachers or through the media. Thus, prior knowledge and experience of the students in which learning takes place play an important factor in the construction of knowledge. Students build strong conceptual frameworks when instructors help them clarify prior knowledge through active learning (Ambrose et al., 2010). According to constructivist theory of learning, knowledge is uniquely constructed by each individual learner and the learner actively constructs knowledge to sensitize the events of the world. Another important thing is that the students' conceptions before instruction are not properly analyzed and hence there is a gap between teacher-student communication and interaction.

According to constructivist view of learning, meaningful learning occurs when the learners actively construct their own knowledge by using existing knowledge to make sense of newly gained experiences. Thus, the first step is to be aware of the learners' current ideas. The learners' preconceptions and misconceptions on the process of developing new knowledge should be highlighted. Remedy can be undertaken through conceptual change approach. The pre-condition is that students' pre-knowledge and experience must be intelligible so that students can be able to understand accurately. Further, the more complex teaching concepts should be arranged in a hierarchical manner moving from known to unknown, simpler concepts to complex concepts in reference to conceptual understanding. The task of organizing the concepts requires a kind of mapping known as ‘Concept Mapping’.

### Misconception defined

Misconceptions are more than misunderstandings about a concept. Misconception is defined as knowledge which obstructs to learn scientific knowledge due to personal experience. So, these are wrong concepts that a student accepts as true. This arises based on local and every day’s experience. The experience obtained from everyday events is not organized. It is somewhat distorted, even with several variations. Every day’s experience is a wrong notion which is built in the minds of young students. It follows either correct or incorrect pattern. Pre-existing ideas held by students that are confusing to new thinking about the natural world are generally referred to as misconceptions. Thus, students’ ‘hard-core’ beliefs and notions are accountable towards misconceptions. According to researchers different and multiple connotations are described. Makonye (2012) explained misconceptions are the underlying wrong beliefs and principles in one’s mind that causes a series of errors. Researchers use labels such as ‘alternative conceptions’, ‘preconceptions’ and ‘alternate frameworks’ to imply that these ideas are not completely ‘wrong’ in a student’s common sense world. Students’ pre-conceived ideas, conceptual misunderstandings and factual misconceptions are labelled under these categories of misconceptions.

### Rationale of the study

Students enter the classroom with their own ideas and belief systems about the world. These preconceptions may come from a variety of informal sources. Such incomplete ideas persist as misconceptions. Certain ideas may be incorrectly interpreted from students’ observation. It shows that such fixed personal understandings are hard to root out, even after teachers provide correct information. Hancock (1990) described that a conception becomes inconsistent with currently accepted scientific views due to faculty reasoning of the students. There rises a difference between students’ ideas and scientific ideas. This difference is ‘mistakes’ or ‘errors’ which misleads ideas. Thus interpretation of facts becomes erroneous. Student’s view and understanding of word meanings are incorporated into conceptual structures which provide a systematic understanding of the surroundings from the students’ point of view. Thus, the students develop inconsistent explanations of scientific concepts. It can be pointed out that students lacking in conceptual knowledge and understanding tend to take place misconceptions in science. It is due to lack of roles of observation, imagination and reasoning about the processes of science. Understanding of the molecular shape is a basic concept to learn the chemical reactions and their mechanisms. But students are lacking in knowledge and understanding of concepts. This may be due to various reasons due to lack of basic knowledge of:

(i) Electronic configurations
(ii) Valency
(iii) Bond-pair
(iv) Lone-pair
(v) Bond angle
(vi) Chemical bonding

After clarifying these concepts the students may be able to recognize,

(i) Valence electrons
(ii) Valency of the elements
(iii) And basics of chemical bonding

Students possessing flaw and misunderstanding of ideas that are strongly held, interfaces with their leaning and causing disinterest and de-motivation towards the subject. So, instruction must confront, diagnose and replace these misconceptions. A search in the literature reveals that textbook, reference books, teacher’s language, cultural beliefs and practices are some of principal sources of misconceptions of many science concepts. Daily experiences and perceptive thinking give rise to students’ misconceptions which ultimately affect subsequent learning. Therefore, the study was undertaken to understand and analyze the students’ hard spots in the learning of ‘shape of a molecule’.

### Objectives

(i) To identify students misconception about ‘shape of the molecule’
(ii) To understand students’ prior knowledge influencing misconceptions
(iii) To create diagnostic tool for the prevention of these misconceptions

### Research questions

(i) What are misconceptions about the shape of the molecule of students?
(ii) Why do students fail to understand these concepts?
(iii) How do we address these misconceptions?

## METHODOLOGY

Action research approach was followed to understand what factors

**Table 1.** Screening test result in frequency distribution.

| Score | Frequency |
|---|---|
| 10 | 1 |
| 09 | 2 |
| 08 | 3 |
| 07 | 8 |
| 06 | 3 |
| 05 | 2 |
| 04 | 4 |
| 03 | 7 |
| Total | 30 |

**Table 2.** Core test on shape of molecule.

| Area of the topic | Number of items |
|---|---|
| Electronic configuration | 06 |
| Valency | 08 |
| Lone pair, bond pair and bond angle | 03 |
| Chemical bonding | 11 |
| Shape and structure of molecule | 02 |
| Total | 30 |

caused students to make mistakes in various sub-concepts of shape of molecule. This approach employed purposive sampling strategy to produce dense description of data. Data were collected from a purposive sample of those students who could provide the maximum information. Those students were in greater risk of committing errors. The sample comprised students of 12 boys and 05 girls, making a size of seventeen.

In order to understand students' prior knowledge, it was necessary to describe misconceptions. The research has several steps: a) screening test b) classroom observation c) document analysis d) core test e) accompanying data analysis to identify the misconceptions f) designing teaching and learning lessons through concept mapping to address misconceptions g) summative assessment h) finally, presentation of results in written formats. The cycle of action research was carried out in the following phases:

Phase I: Engagement with the problem
Phase II: Identifying Misconceptions
Phase III: Analyzing Misconceptions
Phase IV: Action plan

### Tools

The tools for data collection were:

(i) Screening Test- Students were given screening test. The items of the test were asked from general knowledge based on everyday science. It was to test awareness towards science. This test comprised of 10 objective items. On the basis of its result, only seventeen students were selected.
(ii) Core Test- The test items were asked from the five different areas of shape of molecule. This was diagnostic multiple choice type of test. The purpose was to identify the misconceptions
(iii) Document Analysis- copies of problem solving, copies of student evaluation forms and learning log of students were the documents gathered to analyze in order to find out the sources of misconceptions and associated misconceptions on shape of molecule.
(iv) Concepts map on shape of molecule- The linkage between sub concepts were shown through this map to develop conceptual understanding. This was remedial measure to remove the identified misconceptions and to decide teaching approach on shape of molecule by the instructors.

### Data analysis

***Phase I: Engagement with the problem***

A test comprising 10 objective items was conducted to a class of 30 students of 9th standard. The items were of general knowledge type based on everyday science. It was used for screening the students.

***Screening test***

On the basis of this result (Table 1), only seventeen students were selected. It was found that number of students scoring 5 or less than 5 is thirteen (43.32%); greater than 5 are seventeen (56.68%). In order to capitalise on cognitive potential, the students scoring above the mean score with one standard deviation were screened (Vygotsky, 1978).Thus, the number of participants of the study was seventeen. It was reasoned that if the slow learners were placed with faster students they would lag behind as the teacher might not have enough time to cater for students who learnt at different rates. The sample constituted 12 boys and 05 girls, making a size of 17.

***Phase II: Identifying misconceptions***

**Core test:** The test was about the students' concepts on shape of molecule consists of 30 multiple choice questions. The multiples had four possible answers out of which one was correct. The question was scrutinized by a panel of experts in chemistry and two science teachers in order to maintain validity of the questions. All the items criticized were improved or rejected from the final version. The questions were sub divided into five categories. This test was administered to the sample constituting seventeen participants. The particulars of five different areas on shape of molecule which were not answered by all are given in Table 2. The results are presented in Table 3.

Based on correct and incorrect answers it was found that highest score is 11 and lowest score is 5. The average score is 8.82.

***Phase III: Analyzing misconceptions***

Students' exercise book responses and copies of student evaluation sheets were the documents gathered to analyze. The difficulties in the following concepts were identified (Table 4 and Figure 1).

## RESULTS

(i) Particular items related to chemical bonding were attempted by all
(ii) Performance of girls were better in comparison to boys

**Table 3.** The core test.

| Score | Frequency | Performance in percentage |
|---|---|---|
| 11 | 1 | 5.88 |
| 10 | 6 | 35.29 |
| 9 | 3 | 17.65 |
| 8 | 5 | 29.41 |
| 7 | 1 | 5.88 |
| 5 | 1 | 5.88 |
| N | 17 | |

**Table 4.** Core score in hard spots.

| Roll number of the student | Chemical bonding (out of 11) | lone pair bond pair and bond angle (out of 3) | Valency (out of 8) | Electronic configuration (out of 6 ) | Shape and structure of molecule (out of 2) | Total (out of 30) |
|---|---|---|---|---|---|---|
| 11 (Girl) | 5 | 2 | 4 | 0 | 0 | 11 |
| 21 | 3 | 2 | 3 | 2 | 0 | 10 |
| 25 (Girl) | 3 | 2 | 3 | 2 | 0 | 10 |
| 24 (Girl) | 3 | 2 | 3 | 2 | 0 | 10 |
| 05 (Girl) | 3 | 2 | 3 | 2 | 0 | 10 |
| 06 | 3 | 2 | 3 | 2 | 0 | 10 |
| 20 (Girl) | 3 | 2 | 4 | 1 | 0 | 10 |
| 07 | 3 | 2 | 3 | 1 | 0 | 9 |
| 03 | 3 | 2 | 3 | 1 | 0 | 9 |
| 13 | 3 | 2 | 3 | 1 | 0 | 9 |
| 12 | 3 | 2 | 2 | 1 | 0 | 8 |
| 08 | 3 | 2 | 2 | 1 | 0 | 8 |
| 04 | 4 | 0 | 1 | 3 | 0 | 8 |
| 16 | 3 | 2 | 2 | 1 | 0 | 8 |
| 10 | 3 | 2 | 2 | 1 | 0 | 8 |
| 23 | 3 | 2 | 2 | 0 | 0 | 7 |
| 14 | 2 | 2 | 1 | 0 | 0 | 5 |

(iii) Most of the students (sixteen in number) attempted questions related to Lone pair bond pair and bond angle
(iv) Most of the students (thirteen in number) attempted questions related to valency of Aluminium, whereas none were able to find the valency of Sodium (Na), Chlorine($CL_2$), Oxygen ($O_2$) and Magnesium ($Mg_2$)
(v) Lack of knowledge about fundamentals of modern periodic table
(vi) Lack of knowledge of differences between metal and non-metal elements
(vii) Most of the students ( eleven in number) were not able to define the atomic number of carbon
(viii) Some could recognize the electronic configuration of Sodium (Na), But all failed to find in case of Chlorine ($Cl_2$)
(ix) Differences between ionic and co-valent bond is known to anybody.
(x) No one was able to define valence electron
(xi) It was also unknown to all about symbolic representation of atom with respect to atomic number and mass.
(xii) Basic questions related to chemical bonding like naming of bond, example of polar bond and covalent bond were completely unanswered by all

The students were deviating away from scientific explanations when they were explaining the natural phenomenon of bonding. They were not capable to illustrate the key terms included in the content for clarification. This led to develop faulty ideas. It was due to their life experiences. They were not able to reason out on the basis of their observation about daily life experiences. They were never exposed to an open discussion. They could not maintain to find alternative solutions rather, they pressed to ‘the right answer only’.

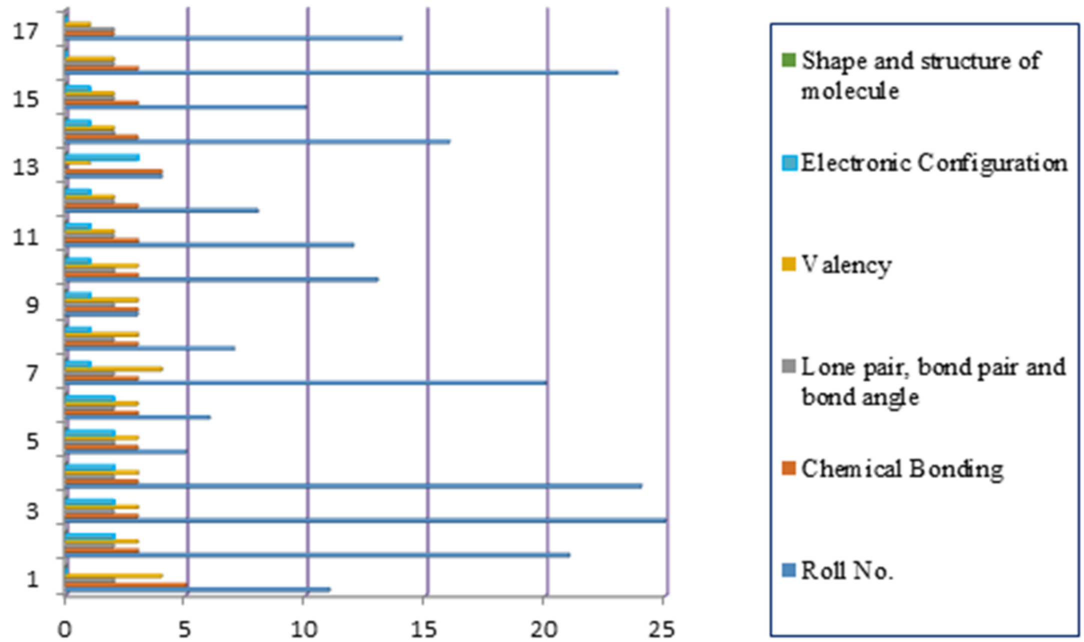


**Figure 1.** Number of students getting correct answer.

Hence, students were lacking in their conceptual understandings. Further, students expressed that there was no use of models or analogies from daily life experiences to illustrate those abstract concepts like atom, molecule, electron, valency and molecular shape. So, the teaching approach on shape of molecule was another criterion to create misconceptions.

**Phase IV: Action plan to address misconceptions**

A table of Action plan is presented (Table 5).The two research questions based on identifying misconceptions and how to deal with those misconceptions are answered in this plan. The concepts map will facilitate learning by helping the learner to incorporate a large volume of information and concepts. It is the structuring of content as the basis of deciding how to sequence and synthesize the concepts of shape of molecule (Figure 2).

## DISCUSSION

Misconceptions are the gaps in knowledge that need to be filled. The students were not simply lacking information about science concepts; they had developed their own explanations for it. Our instruction searches for gaps in the pre-requisite knowledge and go forward, rarely looking back for reasons beyond the summative assessment. If the students' cognitive abilities are not enough mature to understand the concept, they will not be able to develop a correct understanding of it, regardless of instruction. The cognitive and metacognitive learning strategies of students help to grow motivation, awareness and self-directed learning readiness (Xuan et al., 2018). Meta cognition helps to evaluate own understanding, formulating one's own plans and keeping record of learning performance. The students asked questions for clarification in order to be engaged in learning context. Proficient learners use more strategy in terms of meta-cognitive and social strategies during learning activities (Salahshour et al., 2013). The learning activities have directly and indirectly acceleration in acquisitions of meaningful learning (Sailin and Mahmor, 2018). Misconception can be attributed to faulty information that the student accumulates from the external sources like peer, parents, internet and other reading books.

Teachers should create a non-threatening environment. Actually, all acts of class room are geared to facilitate a learning environment. This study in science education was directed towards focusing on expression of the child's personal ideas. Constructivist theories of learning articulate the process of conceptual change in school science. The students were encouraged to make explicit their existing ideas. Each student had his/her distinct potential. Therefore, various activities emphasizing on multiple intelligences were required to tap the student potential (Azid et al., 2016). Within a supportive environment, a high level of trust, warmth and enthusiasm is developed. Hence, the teacher conveyed warmth and above all an atmosphere of respect for the students and their co-learners. Students were encouraged to know conceptual framework by discussing

**Table 5.** Action plan.

| Summary of research question | Summary of misconception | Recommended action | Resources necessary |
|---|---|---|---|
| | Orbital | Interactive method based on Periodic Table | Chart of periodic table |
| | Electron configuration | Using a periodic table with shell and sub-shell designations in each square, students learn the patterns of electronic configurations of the elements. | chart showing electron configuration |
| | | Students are encouraged to commit these patterns to memory through rehearsal in class | Concepts map on shape of molecule |
| Electronic configuration | | Diagrams that represent electron levels and sublevels with the corresponding values of question numbers are designed. The diagram helps to explain the atomic structure to the students according to Hund's rule. | Written Summative examination |
| | | The relationship between periodic table and the atomic structure of chemical elements by demonstrating the construction of the periodic table will be explained | |
| Valency | Periodic table | Shape of molecules will be explained with the help of molecular models | |
| | Atomic number | You Tube video presentation | |
| | Valence electrons | Learning log by students | |
| Lone pair, bond pair and bond angle | Repulsions between electron pairs in the valence shell | | |
| | Magnitude of repulsions between bonding pairs of electrons | | |
| | Molecular orbital | | |
| | Position of valence electrons in molecular orbital | | |
| Chemical bonding | Ionic bond | | |
| | Covalent bond | | |
| | Metallic bond | | |
| | Stable electronic configuration losing electrons/gaining electrons/sharing | | |

with other students and thinking about the evidence. Collaboration between students in the form of giving and receiving peer feedback on student–directed learning task facilitated learning (Dixon and Wu, 2014). Discussion to a large extent helped learners to overcome their errors and misconceptions. The discussions encouraged them to think about their thinking. These cognitive processes enabled the learners to deal with their errors as they learnt from their peers. By the way, they recognized and transformed their 'shape of molecule' conceptual structures. Assessing and re-assessing the validity of students' misconceptions are also necessary. So, learning log was maintained and reflections on misconceptions were practised by the students. Thus, implementing activity methods, student centered activities, experimenting and improvisations through plan, Do, See and Improve (PDSI) in class room practices in science education can be better for conceptual understanding of students (Ndirangu, 2017).

## CONCLUSION AND RECOMMENDATIONS

More often, classroom evaluation places heavy emphasis on recall/recognition of information. Students learn it within a broader framework of meaningful inter-

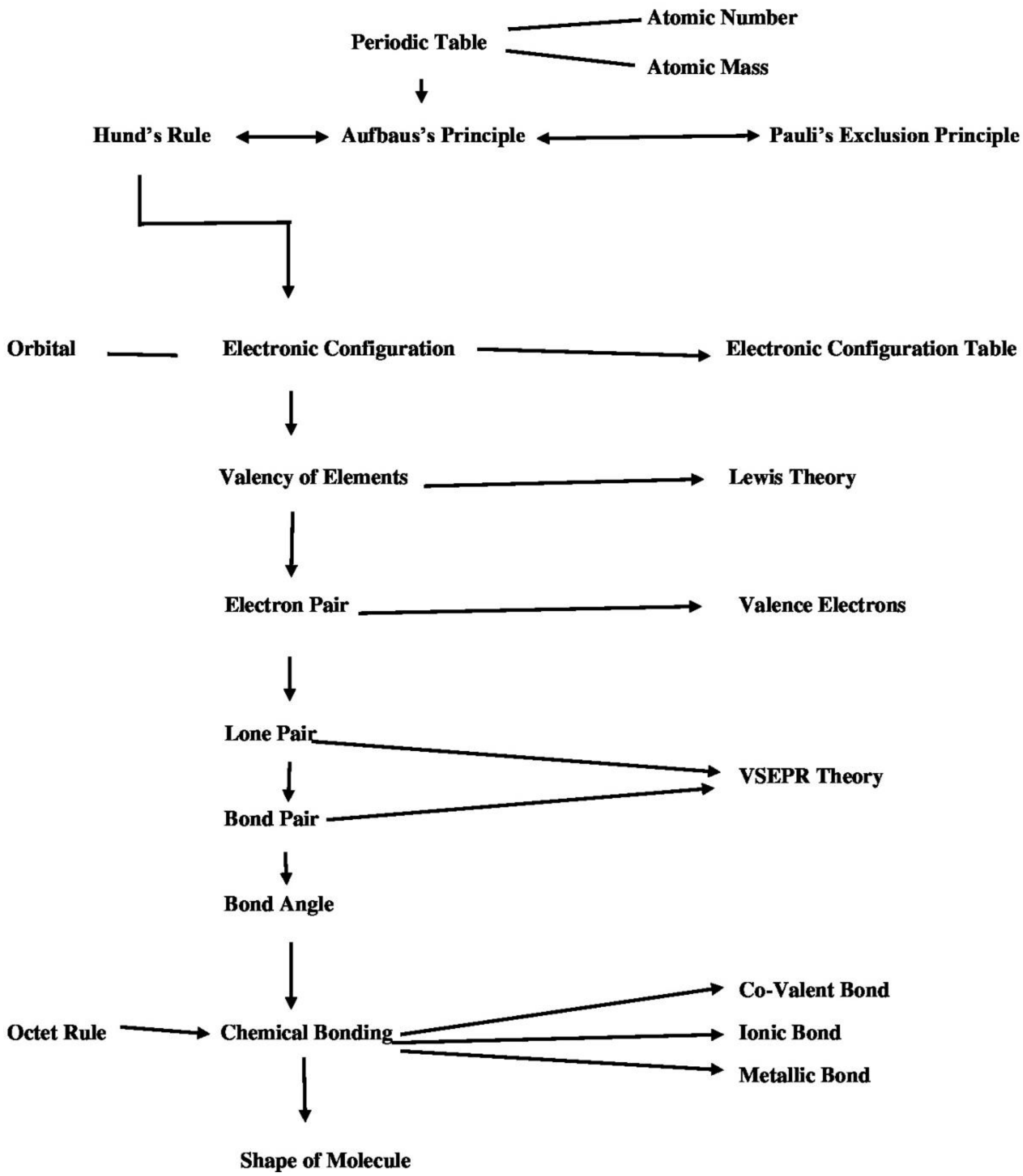


**Figure 2.** Concept mapping on shape of molecule.

relationships and understandings. On this reason there is a need to make deep learning to foster development of this goal through evaluations of students. This requires that we should emphasize on understanding, transfer of learning to untaught problems and contents. Class room evaluation also affects students in many ways: guides their judgement of what is important to learn, affects their motivation and self-perceptions of competence, and structures their approaches to and timing of personal study. So, a more effective approach to evaluation demands regular and thoughtful analysis by teachers through peer reviews procedures and attention to their progressions. Evaluation has played little on its role in assisting students to learn. The pivotal role of evaluation in teaching and learning needs to be integrated in order to learn strengths and weaknesses. Emphasis of feedback on personal progress can clearly demonstrate mastering educational tasks.

## Future work directions

This research throws light on misconceptions and how to address through the instruction. Research is needed on how content knowledge impacts into a teacher's ability to address the misconceptions in the classroom. Another area of direction is on limited expertise in assessment in order to identify the errors. Research may be directed to study how students are interpreting and integrating new content to guide their instruction.

## CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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