The New Education Policy (1986) sought to involve teachers in defining and sharing effective teaching-learning practices. However, from a political perspective, educational progress across the curriculum was far too slow and uneven. Government framed and revised policy time to time to include teachers for various activities of national and curriculum importance. This forced a considerable reduction of flexibility and autonomy (and enjoyment) and a loss of available time and energy, because of much enhanced accountability and curriculum pressure. It was particularly significant since this inhibits teachers’ engagement in research, development or even in reflective practices in their own classrooms. Scoring students’ hundred percent result on the basis of mugging up the contents, can establish a teacher as qualified or effective or best? This paper is trying to provide a detailed specification of teachers’ necessary science knowledge.

1. INTRODUCTION

Teachers differ from scientists, not necessarily in the quality or quantity of their subject matter knowledge, but in how that knowledge is organized and used. The focus of educational research is very heavily weighted towards conceptions of students, implicitly assuming that chemistry teachers know the right scientific answers for each and every problem. There is, of course no argument for careless reasoning or sloppy vocabulary, but surely it is part of any pattern of careful thinking that meanings and significance of words and ideas are constantly re-evaluated? What is unique about the teaching process is that it
requires teachers to transform their subject matter knowledge for the purpose of teaching. Pedagogical content knowledge is highly specific to the concepts being taught, is much more than just subject matter knowledge alone and develops over time as a result of teaching experience. This forced a considerable reduction of flexibility and autonomy (and enjoyment) and a loss of available time and energy, because of much enhanced accountability and curriculum pressure. It was particularly significant since this inhibits teachers’ engagement in research, development or even in reflective practices in their own classrooms. These new governmental constraints have also spread to teacher education and training. Those responsible for the educational system seem to see science education as a repository of certainty and getting it right as the main prerequisite for science teachers. They also seem to see learning as a relatively unproblematic or mechanistic process that requires only clarity from the teacher and sufficient hard work on the part of the student, for the material presented to be learned. It is sufficient for a learner to qualify any examination but is it sufficient for a learner to understand what he or she is doing or learning? Scoring students’ hundred percent result on the basis of mugging up the contents, can establish a teacher as qualified or effective or best? This paper is trying to provide a detailed specification of teachers’ necessary science knowledge.

2. LITERATURE REVIEW

According to Driver and Easley (1978), Bodner (1986), Nakhleh (1992) and Garnett et al. (1995) that much has been written about constructivism in Chemistry and the ways in which learners make sense by constructing meanings and explanations for themselves. However, of greater concern is the relative lack of impact that most research into chemistry learning has had on the practice of chemistry education in schools and university classrooms and the very small numbers of practicing teachers who have an interest in educational research (de Jong 1999).

3. PEDAGOGICAL CONTENT KNOWLEDGE

Pedagogical content knowledge is a type of knowledge that is unique to teachers and is based on the manner in which teachers relate their pedagogical knowledge (how to teach) to their subject matter knowledge (what to teach). It is a form of knowledge that projects science teachers as teachers rather than scientists (Gudmundsdottir and Shulman 1987). Teachers differ from scientists, not necessarily in the quality or quantity of their subject matter knowledge, but in how that knowledge is organized and used. Cochran et al. (1993) revised Shulman's original model to a model that results from an integration of four major components; Subject matter knowledge, Pedagogical knowledge, Knowledge of students’ abilities and learning strategies and Subject matter expert with mode and concepts clarity.

A topic of Photosynthesis can be taught differently by different Educators. Physical chemist will see more of physics in it. Inorganic chemist will stress on water and nutrients and Organic chemist will stress for energy and various forms of compounds formed. Biologist may stress more on physiology but may forget to tell about chemistry
behind that. Physicist may try to find physics laws behind that. Little or inappropriate knowledge, understanding and attitude lead to misconceptions. The topic photosynthesis may have different values for different experts but the learner needs one and comprehensive approach. Carpenter et al. (1988), Feiman-Nemser and Parker (1990) and Gess-Newsome and Lederman (1993) mention that novice or inexperienced teachers tend to make broad pedagogical decisions without assessing students' prior knowledge, ability levels, or learning strategies because they are not expert in content fields and base teaching decisions. Research is needed to find the appropriate methodology to make students understand the contents properly and accurately.

The focus of educational research is very heavily weighted towards conceptions of students, implicitly assuming that chemistry teachers know the right scientific answers for each and every problem. While teaching a lesson or writing a book, when such people demonstrate alternative conceptions, these mistakes are simple deprecated. It is not mentioned to highlight such people but it is argued here that we all carry with us facets of basic chemical knowledge that may not pass muster when subjected to critical examination by others. This is inevitable and however much one strives for absolute correctness at whatever level some uncertainty will remain. Even after going through very careful preparation for writing an article or presenting a teaching session there can be no absolute assurance that everything will be correct.

Uncertainty, ambiguity and fuzziness are inevitable and an integral part of the epistemology of chemistry. Certainly students need to accept that sense making is integral to the doing and learning of chemistry. This is why educators should try to use words carefully, define terms, state laws as clearly as possible and continually match and rematch these ideas with experience and the ideas of others. Science (chemistry) education is being pushed towards greater certainty, greater emphasis on test and examination scores, greater bureaucratic accountability and less flexibility, autonomy and professional satisfaction (and fun) for science teachers and their students - all in the name of higher standards. Perhaps there was too little certainty and consistency during earlier times but we now seem to be losing balance in the opposite direction. Some uncertainty legitimates, indeed requires questioning, contribution, debate, invention and ideas from teachers and students. Too much uncertainty or certainty will make science (chemistry) too complex, difficult to learn and impossible to teach. Wong (2001) considered an appropriate flavour of uncertainty for the health of science (chemistry) to be good.

It is very important to substantiate or clarify the students’ misconceptions and pseudo-conceptions before starting teaching-learning process. Without aligning and catalyzing the scientific contents and pedagogical approach with current scientific views and knowledge, no curriculum or lesson can be re-fabricated or simplified or re-characterized. The new approach should be based on learners’ views. A single or uniform pedagogy cannot the serve the purpose for each and every type of content. Chemistry cannot be taught by the way of other sciences or commerce and humanities. A different approach specifically for chemistry only can justify the teaching-learning process. The
model mentioned in the figure for example, can be applied to “Concept of Chemical Bonding” an important topic in chemistry.

![Teaching-Learning Model for aligning and Catalyzing the Approach and Process for Easy Learning in Chemistry](image)

**Figure 1: Teaching-Learning Model for aligning and Catalyzing the Approach and Process for Easy Learning in Chemistry**

### 3.1 Normal Learning Outcomes

For the topic under study, normal learning outcomes may be as following:

i.) Explain the concept of chemical bond,

ii.) Draw the structure of hydrogen molecule or hydrogen chloride showing chemical bonds,

iii.) Show and explain the strongest/weakest bond in a given drawing of a molecule,

iv.) What are different types of chemical bonds,

v.) Recognize chemical bonds in different contexts,

vi.) Recognize the atom or atoms containing the greatest/lowest electron density in a given molecule and justify your answer,

vii.) Provide a list of characteristics of a certain material regarding a given structure (model) and explain each characteristic, Etc.

### 3.2 Sequential Stages under the New Adopted Approach

Data or details pertaining to the topic under study needs to be gathered and analyzed for the simplification and better performance. This may have following perceptions and aspects:

a) Contents in chemical bonding, and
b) Pedagogical insights regarding the teaching approach.

The sequential steps may be as given below:

i.) Segmenting and categorizing the topic under study into simpler forms to attract big ideas, principles, visuals, etc.

ii.) Developing more general domains to find learning goals, objectives and teaching strategies.

iii.) Mapping all the simplified forms according to the chosen and developed domains.

iv.) Re-organization of data and details as per mapped and chosen domains.

v.) Proposing assertions based on the accumulated data, which will hopefully contribute to a better understanding of the studied issues.

### 3.3 Pedagogical Insights into Teaching of Chemical Bonding

Hurst (2002) suggests teaching bonding by presenting all types of chemical bonds based on one central model, since they all result from electrostatic forces; presenting the bonds as different entities, as is often done in textbooks, is misleading. Traditional approach or lecture method by which this concept is presented is not only nonscientific but may also generate pedagogical learning impediments.

i.) The heart of the problem in teaching chemical bonding is the wrong presentation used by teachers regarding various structures that can be explained by different bonding types.

ii.) The explanation regarding the formation of chemical bonds must rely on the principle of minimum energy and not only on octet theory. Often the presentation of bonding and energy is separated and the concept on energy is introduced later. These two ideas must be linked. The concept of bond energy is essential for understanding the bonding concept.

iii.) The chemistry lessons should be taught differently - to make students understand and not just memorize. Learners must be equipped with the scientific tools that will assist them in formulating scientific reasoning with such tools they can think, get intuition, act, perform, etc.

iv.) Questions need to be framed and asked regarding typical tendencies of chemical properties that can be scientifically explained by the students.

v.) New teaching approach should be accepted enthusiastically.

vi.) Things need to be simplified and provided to students with generalizations and rules because chemistry must be presented as an exact science.

### 3.4 Re-characterizing the Teaching of the Bonding Concept

Based on pedagogical insights, sequential stages and other details, the following key-learning goals can be formulated:

i.) Developing an understanding that all chemical bonds are electrostatic forces according to Coulomb’s law.

ii.) Developing an understanding that chemical bonds cannot be described by a set of rigid definitions or through a dichotomous classification.
iii.) Developing an understanding that common concepts and elemental principles should be applied for chemical bonds between two atoms first and then to molecules and lattices.

iv.) Developing an understanding that there is a whole range of chemical bonds, which can be mapped on a continuous scale according to the strength of electrostatic forces.

v.) Developing an understanding that there are a small number of principles and key concepts that are central and common for all chemical bonds, such as attractive and repulsive forces, the equilibrium point, bond energy, bond length, and electronegativity.

vi.) Encouraging the ability to explain scientifically some chemical phenomena and to realize that all phenomena cannot be explained by same model.

vii.) In order to calculate and obtain solutions for bonding problems, quantum mechanics is the accepted quantitative theory.

viii.) New tasks should be developed based on learning performances, which examine deep understanding and improve students’ ability to apply these concepts to a variety of situations.

3.5 Approaches for Teaching Chemical Bonding

Chemical bonding includes simple electrostatic force of attraction from simple atoms to molecules and lattices to complexity and their properties. There exist different types of attractions or chemical bonding: Ionic, covalent, coordinate covalent, metallic, H-bond, vander waal’s forces, etc. and there exist different type of lattices like ionic, molecular, covalent, metallic, etc. The topic chemical bonding can be studied in the following way:

i.) Single atom, existence and forces of attraction

ii.) Meeting of two atoms lead to development of electrostatic forces of attraction, why? Electronic structure, electronegativity, bond energy, bond length, etc. can be explained.

iii.) Concept of Vander Waal’s forces, H-bond, etc. can be studied.

iv.) Concept of different bond lengths, different bond energies can be explained.

v.) Single polyatomic molecules, structure, polarity, etc. can be explained.

vi.) Studies can be shifted to molecules, simpler, complex, giant, etc.

vii.) Properties and phenomena of materials with respect to aspects of bonding and structure can be studied.

That study is always better which improve students’ ability to apply their knowledge in a variety of contexts aligned with the learning performances.

3.6 Learning and Performance

Taber and Watts (2000) suggested that we should expect chemistry students to acquire some familiarity with the theoretical frameworks of current science and to develop some level of proficiency in applying their knowledge regarding chemical bonds in order to produce valid scientific explanations. If any learner is asked to answer “Which material
has a higher boiling point - LiF or HF? Justify”. The answer “The boiling point of HF is lower than the boiling point of LiF because the hydrogen bonds between the HF molecules are weaker than the electrostatic forces between the negative ions and the positive ions in the ionic lattice LiF” is correct but it cannot be concluded that the learner answered the question by cramming or the learner really understands the concept behind it.

Here requires New Assessment Task or the Verification of Learning Outcomes. Learner may be asked “In the liquid and the solid states of water there are hydrogen bonds between the molecules. Explain in your own words what hydrogen bonds are” and “Give an example of another molecular compound in which hydrogen bonds might occur and explain why and how they may be formed”. The correct answer to these questions lead to the view that learner has not crammed but understood the matter. According to Pellegrino et al. (2001), alignment of assessment tasks, with well-specified key-learning goals as well as with learning performances, is essential for students’ meaningful learning, and it enables examining a deeper understanding.

4. DISCUSSION

There is a statement about people’s understandings of science that there is no single knowledge gap between scientists and non-scientists, but there is, instead, a multitude of specific gaps between specialists and non-specialists in each field. Surely all scientists should agree on the meaning of basic words in our vocabulary? Unfortunately it seems that this can never be the case since our words carry with them our interpretations, experiences, beliefs and sometimes even our emotions. When others receive the same words it is their meanings they hear. Words do not restrict their meanings to one particular definition even if there is a meaning carrying the IUPAC endorsement. It is necessary that the words have the same meanings, especially when considering exchanges between novice learners (students) and more experienced learners (teachers). It does not really matter whether neutralization is a redox reaction or whether carbonated drinks boil when poured into a glass. That is unless the belief of teacher/examiner differs markedly from learners. This provides pressure for students to learn (and be taught) right answers that do not necessarily make sense. The key concern here is that we learn to tolerate that there can never be a uniform set of meanings for words within the scientific community. We must expect meanings to develop and be prepared to renegotiate meanings as we learn. There is, of course no argument for careless reasoning or sloppy vocabulary, but surely it is part of any pattern of careful thinking that meanings and significance of words and ideas are constantly re-evaluated? It is not helpful in the long term to learn meaningless words by rote. This relates to the wider issue of teacher competence. The competence required is an ability and confidence to, not only present science to their students, but also to contend science with their students (Goodwin 2000). This is necessary to have:

- Proper justification for its place in the curriculum.
- For society and individual students.
- An appropriate balance between passing examinations and learning science.
Dr. Avtar Singh Rahi: Chemistry Pedagogy Links Teachers To Learners

A continuing enthusiasm for learning by the teacher.
The critical engagement of students.
To develop students’ autonomy in learning.

The teachers require a robust and consistent story of science for themselves but it must remain legitimate for them to be continually learning and not to have known before they began teaching. What is unique about the teaching process is that it requires teachers to transform their subject matter knowledge for the purpose of teaching (Shulman, 1986). Pedagogical content knowledge is highly specific to the concepts being taught, is much more than just subject matter knowledge alone and develops over time as a result of teaching experience. The present study is in favour of establishing scientific frameworks that prevents pedagogical learning impediments; induce deeper understanding of the fundamental nature of topics in chemistry and realistic explanations of phenomena and introducing new assessment approaches.

5. CONCLUSION

The science (chemistry) being learned by any individual is at the boundary of their experience and, if it is to be useful it must be significant and make some kind of sense. Teachers themselves gain insights by learning with their students and this requires mutual respect of ideas as well as continuous critical evaluation in both directions. Questioning and uncertainty must be legitimate within the framework and development of national guidelines, syllabuses, programs of assessment and patterns of qualification. It is a ‘question of balance’, but it seems that if we are to make progress in becoming scientists or doing science - and perhaps even in remaining human - nothing must ever be quite certain. A Chemistry teacher evolves or establishes only if the any expert critically reflects on and interprets the subject matter; finds multiple ways to represent the information as analogies, metaphors, examples, problems, demonstrations, and/or classroom activities; adapts the material to students' developmental levels and abilities, gender, prior knowledge and misconceptions and finally tailors the material to those specific individual or groups of students to whom the information will be taught.

6. REFERENCES


