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RESEARCH ARTICLE

UNDERSTANDING STUDENTS' VIEWS ON THE NATURE OF SCIENCE.

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Abstract

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This study sheds some light on the commonly held views of senior secondary students about the nature of science. The study is framed around the philosophical positions on the nature of science and elaborate treatment of its various aspects as given by Lederman (2002). The study is purely qualitative and emergent and has been conducted in the Indian context. Samples of the study are school children who have opted science and the college students who are in the first year of graduation course with chemistry as one of their major subjects. In this study, we have tried to describe how students perceive science to be and how it works along with trying to present an emerging relationship between their understanding of the nature of science and their interest in and appreciation of science. Furthermore, taking insights from many studies (Mc Comas, Almazora and Clough (1998)) that chemistry textbooks have an important role in shaping ideas and understanding of concepts in science and the nature of science, we reviewed the NCERT chemistry textbook looking for representation of some aspects of the nature of science. This book is chosen because of been relied upon heavily by students and teachers as the main source of information in Indian schools. Also, looking at the current trend worldwide (Nuffield Projects, PISA documents) there was a felt need how NCERT textbook fare on the yardstick of parameters set to decipher the effectiveness of chemistry concepts taught to the children. We also have used in this study the Niaz and Fernandez (2008) framework to review a chapter on 'structure of atom' looking for the representation of Historical and Philosophical treatment of the chapter.

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Major findings reveal that college and school students had almost the same views about the nature of science. Textbook writing needs to incorporate the style of presentation which doesn't distort the real science, its nature and how it develops. The textbook reviewed for the chapter 'structure of atom' was not written as per the historical and philosophical framework. Students didn't appreciate the need to study older theories. Several such findings are enlisted in this study. Thus, this study presents how actually this study was conceptualized, took its course and finally manifested in the form of results, findings and discussions which we would like to share with you.

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Introduction:-

Understanding the Nature of Science:-

Science is so much part of our everyday life that we find it impossible to stand back and examine its social context. Our policy documents NCF 2005 and Position Paper on the teaching of science (NCERT, 2006) talk about the development of 'scientific literacy' in all citizens. 'Scientific literacy' means the ability to use scientific knowledge to make informed personal and societal decisions. This further implies that people need to be able to distinguish between good science, bad science and non-science and make critical judgments about what to believe in. They also need to be critical consumers of science. For example, in order to understand and evaluate the scientific advice on food safety, an adult would need to not only know some basic facts about the composition of nutrients, but also to be able to apply that information. The term "literacy" is used to encapsulate this broader conception of knowledge and skills (OECD/PISA, 2003; Ramanna, 1981).

There are different researches which emphasize on different dimensions of scientific literacy or some even look at it under the rubric of public understanding of science. However, an adequate understanding of the nature of science is underlined as a central component of scientific literacy (AAAS, 1993).

The nature of science is characteristic of science. It reflects the values and assumptions that demarcate scientific knowledge and science from other disciplines. It is referred to as knowledge about science. The nature of science is directly related to the epistemology of science as distinct from scientific process and scientific content. The phrase 'nature of science' is used to describe the intersection of issues addressed by the philosophy, psychology, sociology and history of science.

Despite the acknowledged importance of the nature of science, a number of studies document students' misconceptions concerning the nature of science (Lederman, 1992; Meyling, 1997;) on some aspects which include tentativeness of scientific knowledge, social and cultural aspects of scientific knowledge, and the theory-laden nature of observation. Textbooks on which a majority of students depend for their understanding of scientific knowledge are often devoid of presentation of issues dealing with the nature of science. Despite the advocacy at the policy level, they continue to present scientific knowledge as final, in a 'rhetoric of conclusion' (Schwab, 1962).

In continuation of our interest to explore the understanding about the nature of science (Dabas, 2010; Rampal, 1993; 1992) and to relate to the readings undertaken as part of the master's course in science education, this study was carried out to assess students understanding about the nature of science at school and college levels.

Philosophical Positions on the Nature of Science:-

The construct of the nature of science has a history of more than sixty years, which has been influenced by various philosophical debates. There are different philosophical positions on the nature of science, such as, positivism, inductivism, hypothetico-deductivism, contextualism and relativism. It often becomes difficult and complex for people working in the area of science education to define it. However, the way NOS is viewed by McComas, Clough and Almozroa, (1998**,** p**.**4**)** presents a comprehensive perspective "A fertile hybrid arena, which blends aspects of various social studies of science, including the history, sociology, and philosophy of science combined with research from the cognitive sciences such as psychology into a rich description of what science is, how it works, how scientists operate as a social group and how society itself both directs and reacts to scientific endeavors".

However, according to Lederman (1992) the nature of science typically has been used to refer to the epistemology of science, science as a way of knowing, or the values and beliefs inherent in the development and validation of scientific knowledge cited in abed-El-Khalick et al. (2008, p. 837). These philosophical positions on the NOS generally cannot provide a simple framework within which school science could look at issues related to the nature of science.

In the 1960s the nature of science used to be viewed mainly as observing, hypothesizing, interpreting data and designing experiments i.e. primarily science as process skills. It was believed that accurate observations lead to scientific knowledge and thus a good observer was taken as 'objective' and 'theory free'. In school, students were expected to spend more time in the laboratory making observations, even if they were not necessarily constructing knowledge. Objective observations coupled with inductive reasoning gave a greater focus to the so called "scientific method" (Dabas, 2010).

As with the shift in the trend from positivism to constructivism, educationists too made a shift from a 'science centered' to 'student centered' view of school science. The humanistic perspective in science was promoted by Aikenhead (1987) and intended to prepare students to critically and rationally assess science and technology. Stress on the STS approach began to increase because science was no longer seen as happening in isolation. Thus, the nature of science, its social aspects and its human character were sought to be described through the study of the history, philosophy and sociology of science.

Obsorne et.al (2003) conducted an empirical study on experts drawn from among science educators, scientists, historians, philosophers and sociologists, as well as science teachers and then determined the aspects of the nature of science which must be featured in the school science curriculum. These themes, which emerged from the study and from the themes identified by McComas and Olson created a framework of the essential components of the nature of science to be included in school science curricula. Also, it was highlighted that these ideas and aspects of the nature of science have to be taught in an integrated manner and not in isolation and should be fully contextualized. It was also emphasized that the nature of science should be the core of science education and should not be merely confined to margins.

The Nature of Science and 'Models' of the Atom:-

The developments in the area like structure of the atom have immense scope to develop aspects of the nature of science in students. Students in an attempt to understand the models of microscopic entities like 'atom' which cannot be observed directly, need to know the nature and role of observations and inference in reaching out to these conceptions.

They may acknowledge the role of unique ideas which initiated the development of the atomic models in earlier times if the historical/developmental aspect of the nature of science could be developed in them. The structure of the atom traces the history from Thomson to quantum mechanical model; enabling the students to understand the tentative nature of science, the existence of rival theories, creativity of scientists and science as a socio-cultural human enterprise.

These aspects of the nature of science like- tentativeness in science, social and cultural association of scientific knowledge, personal beliefs and theory laden nature of observation if developed in students may lead them to have a more informed understanding about the use of 'models', such as, for the structure of the atom. Moreover, what is observed today, especially in the context of the microscopic world, will change tomorrow due to advancement in technology and knowledge as it has changed since Robert Hooke discovered the cell. So, students might not develop an absolutist view about science, i.e. scientific knowledge is final and that atomic models are exact replica of the 'atom' if these aspects of the nature of science are developed in them.

Science relies on inference and interpretation as all phenomena are not directly observable; for example, inference is used to establish the existence and properties of atoms. The stage at which this concept is introduced, students are normally expected to have developed critical ability to understand the epistemological status of facts, theory, model, and the law that they encounter in science (NCF, 2005). By not properly incorporating the aspects of nature of science, either in teaching learning processes or in the textbooks explicitly, may lead to alternative conceptions among students which gradually keep on being entrenched in their minds. This may create doubt with them about the relevance of the so called 'redundant' theories or models in the syllabus. As was seen during FGD and through the questionnaires, there are students who question the inclusion of Thomson's and Rutherford's models in the syllabus. They might appreciate their work when an understanding about the tentative nature of scientific knowledge is developed among them. They must also appreciate that scientific progress is an evolutionary process and that earlier theories pave way for the newer researches, and that very often new theories might build upon the earlier ones, unless there is a paradigm shift.

Rationale to include the NOS in the Textbook:-

Several scholars had (Driver, 1988; West and Pines, 1985) stressed that until now, attention has mainly focused on traditional science content, though in the last decade content related to the nature of science received attention because of interest in teaching science through the history and philosophy of science (Aikenhead and Ryan, 1992, p.881).

Driver et al (1996) suggested some additional arguments supporting the inclusion of the nature of science as a goal of science education. The arguments include the utilitarian view that "an understanding of the nature of science is necessary if people are to make sense of science and manage the technological processes and objects they encounter…" (p.16).

Theoretical Framework:-

This section will lay out the framework of Lederman et al. (2002), used in the current study to understand the students' views on the nature of science.

Study of Students' Views on the Nature of Science

The present study makes use of the framework developed by Lederman using characteristics about the nature of science to analyze the views of high school and undergraduate students and subsequently reviews the chemistry textbook to see how these aspects are dealt with.
The dimensions of the nature of science in Lederman's theoretical framework are defined as:

The tentative nature of scientific knowledge:-

Scientific knowledge, including facts, theories, and law changes as new evidences are collected or gathered through advances in thinking and technology. It is reinterpreted in the light of new theoretical advances (inferential and creative), or changes in the social and cultural spheres. Contrary to common belief, scientific hypotheses, theories and laws can never be absolutely proven irrespective of the amount of the supporting empirical evidence (Popper, 1959). To be proven, a law should account for every instance of the phenomenon it purports to describe. It can logically be argued that one such future instance, of which we have no knowledge whatsoever, may behave in a manner contrary to what the law states. Thus, laws and theories can never acquire an absolutely proven status. Thus, scientific knowledge, although reliable and durable, is never absolute and certain and always tentative.

The empirical nature of scientific knowledge:-

The empirical nature of scientific knowledge addresses that science is at least partially based on observations of the natural world, and sooner or later, the validity, scientific claims is settled by referring to observations of phenomena (AAAS, 1990, P4). However, scientists do not have direct access to most natural phenomena and observations of nature are always filtered through our perceptions and interpreted from within elaborate theoretical frameworks.

The theory laden nature of scientific knowledge:-

Scientific knowledge is theory laden because it is governed by various factors associated with scientists' theoretical and disciplinary commitments, beliefs, prior knowledge, training, experiences and expectations actually influence their work and what they investigate, how they conduct their investigation, how they interpret their observations. Observations are always guided and acquire meaning in reference to questions or problems, which are derived from certain theoretical perspectives.

The creativity and imaginative nature of scientific knowledge:-

Science, contrary to common beliefs is not entirely rational and orderly activity. Ernest Rutherford conducted an experiment of scattering of alpha particles by gold foil, in 1911.He established the nuclear model of an atom. After he has done an experiment every laboratory assistant could understand it and repeat it. To quote Hospers (1988) "when one reads his work one is always saying, 'why did not someone else think of that?' " cited in Dabas (2010, p.13). It is the imagination of Rutherford which had led him to the gold foil experiment. Thus, science involves the invention of explanations and theoretical entities, which require a great deal of creativity on the part of scientists.

The social and cultural embeddedness of scientific knowledge:-

In an attempt to answer the question- 'whether we should grow crops like corn or jatropha to produce biofuels, we need to know the social and cultural context. Developed countries depend on their industry will favor fuel, whereas developing countries will favor food. Thus, scientific knowledge is socially and culturally embedded.

Observation, Inference, and theoretical entities in science:-

Observations are different from inferences. Observations are directly accessible to the senses or extension of the senses, for example, objects released above ground level tend to fall to the ground. An inference drawn from this can be: 'objects tend to fall to the ground because of gravity'. The notion of gravity is inferential as it cannot be accessed or measured only manifested through its effects.

Myth of the scientific method:-

Discussion on students' responses from the questionnaire shows that they believe 'experiments are the chief route to scientific knowledge'. Of course, experimentation is a useful tool in science, but it is not the sole route to knowledge. Many scientists had used non-experimental techniques to advance knowledge. In a number of situations, true experimentation was not possible because of inability to control variables. Discovery in astronomy is based on extensive observations rather than experiment. For instance, Copernicus theory and Kepler laws used evidence derived from lengthy and detailed observations. Charles Darwin in his discoveries used qualitative techniques, recorded his observations, speculations and thoughts and then reached at conclusions. Sometimes, theoretical advance can also suggest what to look for in an experiment for instance; the concept of antiparticle was first introduced theoretically by Paul Dirac in 1930 and confirmed two years later by the experimental discovery of positron by Carl Anderson (Ejlin, 1999). Scientific knowledge is gained in a variety of ways, including observation, analysis, speculation, library investigation and experimentation.

Scientific theories and laws:-

Within the given framework, the laws are seen as empirical propositions, which describe certain uniformities that exist in the universe, for instance Kepler's laws of planetary motion describe motion of planets. Laws can be verified by experimentation based on observations or based on inferences (Newton's laws).However, in some cases, laws describe what would happen under ideal conditions such as Boyle's, Charles's law for ideal gases, Galileo's laws of falling bodies describe the velocities with which the bodies would fall in a vacuum. Generally, laws are descriptive and discovered.

Theories are inferred explanation for observable phenomena and are tested by experimentation. Scientific theories are well established, highly sustained, internally consistent systems of explanations. A good theory makes predictions, which can be tested for its validity. However, some theories in natural sciences cannot have definite predictions, for example, Darwin's theory of natural selection and survival of the fittest which is a probabilistic theory. Scientific theories are human constructions, but have passed the guessing stage: they have substantive evidence that supports them, but it doesn't become the law, even if very strong support is there to substantiate the theory as many students tend to believe (Meyling, 1997; Ryan and Aikenhead, 1992), but it becomes a more credible theory. Once a theory become established, a large amount of disconfirming evidence is required before it can be challenged. Also, as seen from the students' responses from VOSTS and VOSE questionnaire, the majority of the students held the misconceptions about scientific theories and laws.

Students seemed to have a simplistic, hierarchal view of the relationship between theories and laws whereby theories become laws depending upon supporting evidence. Laws have higher status than theories.

Students' Views about 'Models' of the Atom:-

The framework remained the same as above for understanding students' conceptions of the structure of the atom and atomic models as part of the nature of science. The major emphasis was on the historical as it indicates evolution of scientific truths, philosophical as it emphasizes the importance of a blend of imaginative and logical thinking in the generation of new ideas and epistemological dimensions of the nature of science which is implicit in the knowledge about the structure of the atom and hence possess wide scope to develop these aspects in students.

Review of the NCERT Textbook:-

In this study, a brief analysis of the chapter "structure of the atom" present in the NCERT textbook in India is discussed on the basis of the framework developed by Niaz (1998) and Niaz et al. (2008). A slight modification was done as per the requirement of my research –An additional criterion related to use of thought experiments (Heisenberg's microscope) in understanding the quantum mechanical model was incorporated which already has been used in the study by Malhotra (2013).

The framework is based on the understanding that history, philosophy and epistemology are must to be included in the chemistry textbook particularly in the chosen chapter i.e. structure of the atom. The analysis looks if the NCERT textbook involves these aspects and to what extent. For this analysis, Niaz(1998, p541-542) developed a framework based on the rational recommendations of developments that led to the formulation of atomic models suggesting that the framework will help teachers develop insight as to how a theory or model develops.

The framework was developed by analyzing primary sources like original papers of Thomson, Rutherford, Bohr and some secondary sources. This framework consists of two criteria to evaluate Thomson's model and three criteria to evaluate the Rutherford's and Bohr's models. In addition, five criteria developed by Niaz and Fernandez (2008, p881-883) to evaluate quantum mechanical model were added to the framework. The criteria are discussed in brief:

1. Thomson conducted his cathode ray experiment in the background of controversy against ethereal theory. His experiment aimed at finding out whether the cathode rays were charged particles or waves. The experiment was conducted to find out the mass by charge ratio to investigate whether the cathode rays were fundamental charged particles or ions.
2. Rutherford and his colleagues while working on radioactivity observed something extraordinary which diverted them from their original work towards the study of atom. They had observed that on bombarding the gold foil with alpha particles; 1 in 2000 rays deflected back through large angles and to explain this they proposed a nuclear model of atom. This model had to compete to already existing Thomson's model. Both Rutherford and Thomson tried to defend their theories by giving possible explanations for the results of alpha particle scattering experiment.
3. Bohr's mathematical calculations proved that Rutherford's model was unstable and Bohr decided to address the problem. Bohr thus, proposed a new model of the atom. His main objective was to tackle the instability of the Rutherford's atom. His proposed model was able to explain the line spectrum of the Hydrogen atom, but Bohr himself was unaware of this line spectrum when he proposed his model. The beauty of his model was that it could incorporate Planck's quantum mechanical theory and Maxwell's electromagnetic theory, which are two rival frameworks. Bohr used these two theories to formulate his model and the salient features of his model were quantization of energy and angular momentum.
4. The developments that led to the quantum mechanical model were Planck's and Einstein's contributions to which quantum mechanics provided a better answer. The comparison of the classical and quantum mechanics addresses many misconceptions about the structure of the atom. The quantum mechanical model is analyzed on the basis of success to address a major obstacle for students between orbital and electron density. The last criterion for evaluation of quantum mechanics is related to the concept of quantum numbers, how these are introduced in the textbooks, what is the basis of the formulation of quantum numbers.

On the basis of this framework, many chemistry and physics textbooks have been analyzed.
The above-mentioned studies illustrate that most of the textbooks emphasize on experimental details and observations. There is a dearth of mentioning about how the scientists make decisions, solve problem creatively with incomplete information, propose many hypotheses and judge which fits best and use mental formulation to create theories. The curtailed historical and philosophical aspects in the textbook might give rise to the misconceptions students may possess.

The suggested influence of historical treatment in the topic structure of the atom on the students' understanding of the topic prompted the researcher to look into the NCERT textbook which is accessed by a large number of students.

The Nature of the Study and Methodology:-
The present study has a qualitative research model and requires an understanding of the processes, events and relationships in the context of the social & the cultural situation (Creswell, 2012).

In this study, we wanted to explore how students understand the nature and process of science viz. how science progress, how scientists work as a social group and not in isolation. How the NCERT book (which is the major course book in science curriculum in Delhi) developing essential components of the nature of science in students?

Essential themes of the nature of science in 'structure of the atom' were selected which include historical, epistemological and philosophical aspects of science, tentativeness of theory, observation and inference (conception of atomic models), theoretical embeddedness of scientific knowledge and personal values of scientists affecting their research. The sample size of 30 senior secondary students and 15 undergraduate students were taken and their views were deciphered with the help of a questionnaire. The questionnaire had two sections A and B. Through Section A, we intended to elicit the general understanding about the NOS amongst 11^{th} grade and college students. Whereas the section B was theme specific through which understanding of 'structure of the atom' was probed because it further helped in analyzing students' understanding of the nature of science. The questions were purposefully drawn and modified from VOSTS questionnaire to suit social and cognitive contexts of our learners.

This was followed up by a teaching module which students were asked to read and jot down those points which made better understanding of the topic in them and wanted to be in the chapter 'structure of the atom' in the NCERT. They were also encouraged to write down about those topics which they do not understand by giving reasons (could be pedagogic reasons or language of the book, not interesting illustrations etc.).

The next step was to deeply probe them for what they had answered in questionnaires through FGD (Focus Group Discussion).

Data Analysis:-
Analysis of items in the questionnaire (adapted from VOSE and VOSTS) are done using the frameworks adopted by their developers.

Section A (I) consisted of VOSE items. The framework for analysis is based on a suggestion in the VOSE questionnaire (Chen, 2006). Analysis of the VOSE items is done using a convention that except few statements in the items, the rest of the NOS items may be considered acceptable as diverse views among students and these are not wrong or naive. This convention implies that NOS is not fixed set of beliefs and so students need not conform to certain views. All students cannot have similar views about the nature of science and may perceive science differently and hence its major aspects like nature of science, process, development, scientific activities may be comprehended differently by them.

Thus, students are permitted to have diverse viewpoints about the nature of science. The developers of the test suggest that emphasis should be not on making students possess particular views about the nature of science, but rather urge that provision should be given to students' justifications they give in support of the stance they choose for their views and beliefs about science. The need is pointed towards allowing students to develop their own conception of the nature of science with the scope of discussion in the classroom so that if there is misperceived or alternative conception about science, then that should be brought to an informed level by proper discussion and arguments which should fully satisfy students' curiosity and area of confusion. There is mention that legitimate/ official and accepted knowledge of 'Scientists' and philosophers' should be made known to students, but not taught in a way as to stamp it as if there could be no other valid knowledge than those which are documented in the texts.

The given below are those items which the developers of the questionnaire considered as the partial or incomplete views about the nature of science and considered these views as naïve (immature, raw, inexperienced) views. The items written here are from the questionnaire used for this present study. The numeral and alphabet denotes the item number and option arrangement in the item respectively.

6A, 6B, 6F- Concern with universal scientific method.
6A: The scientific method ensures valid, clear, logical and accurate results. Thus, most scientists follow the universal method in research.
6B: Most scientists use the scientific method because it is a logical procedure.
6F: No matter how the results obtained, scientists use the scientific method to verify it.
9A, 9B- Laws are more certain than theories
9A: Yes, theories are not as definite as laws.
9B: Yes, if a theory stands up too many tests it will eventually become a law; therefore a law has more supporting evidence.
2C, 2D, 2E- Using no imagination in science
2C: No, imagination is not consistent with the logical principles of science.
2D: No, imagination may become a means for a scientist to prove his point at all costs.
2E: No, imagination lacks reliability.
4C, 4D- No influence of socio-cultural milieu on the scientific investigations.
4C: No, scientists with good training will remain value free when carrying out research.
4D: No, because science requires objectivity, which is contrary to the subjective socio-cultural values.
5C, 5D-Highlight no influence of personal beliefs on scientific investigation and observations are considered to be independent of theories.
5C: Observations will be same, because through scientific training scientists can keep aside personal values to conduct objective observations.
5D: Observations will be the same, because observations are exactly what we see and nothing more. Facts are facts. Interpretations may be different from one person to another, but observations should be the same.
We present here, the pattern of responses to VOSE items.

The tabular details of students' responses to all VOSE items are given in Appendix 4. In the parenthesis, I have kept the total number of responses for particular stance i.e. strongly disagree(SD), disagree(D), neutral(U), agree(A) and strongly agree(SA) against the given options and in another line the respective breakup of responses are given for college (C) and school(S) students. As I have explained in detail in chapter 3 about the sample size of both the groups which is: College students =15(F; 7: M; 8) initially and FGD was done with 7 college students (F; 4: M; 3).School students = 30(F; 12: M; 18) initially and FGD was done with 10 school students (F; 4: M; 6).

The following is the analysis of VOSE items:
Item no.1 'when two different theories arise to explain the same phenomenon, scientists will accept the two theories at the same time.' deals with the progress of scientific knowledge which is often characterized by competition between rival theories. Textbooks do not include examples of such nature where controversies and conflicts between theories are shown. The product aspect of science is presented in the textbook as if some theory, model, law, discovery etc. in science is made without actually understanding the kind of situations these scientists had to undergo i.e. no mention about their ecstasy on finding something, fear of financial uncertainty, frenzied stages in the process of discovering something etc. in the textbook which makes science appear smooth and struggle free. So, students might not develop the understanding about science in the making.

The observations which the researcher has made fall on similar lines. The majority of the college (53%) and school (63%) students have similar views on this aspect when they think that two theories which come up to explain the same phenomenon or concept at the same time are accepted tentatively because scientists cannot objectively tell which one is better. 73% college and 92% school students agree with the position that the two theories are accepted because they explain the phenomena with different perspectives, no one being right or wrong.

For another position in this item where, options imply that only that theory is accepted with which the scientists are more familiar and that scientists tend to accept the simpler theories and avoid complex theory; substantial section of students (66% college and around 70% of school students) disagreed with these stances.26% of college students and 50% of school students strongly disagree with this position that academic status of the person who proposed the theory will influence other scientists' acceptance of the theory. Very few students (13% college and 6% school students) take up the stance in favor of it. This might reflect the view of science they have. They might perceive science as secluded, objective, free from human subjective interferences and therefore, they take up those options where science is seen as unaffected by power, prestige and other influences.
There are an equal proportion of sample students who agree and disagree towards the position which says that the theory which deviate less from the current core scientific theory is accepted and the one with more deviation is not accepted.

30% of school students and 26% of college students strongly agree with the position that there is only one truth, and scientists will not accept any theory before distinguishing which is best. This position taken up by the students points towards the general notion that truth is objective and is independent of subject which comes from the strong positivist framework of scientific method. The dichotomy between how science is actually practiced and depicted shows the need to teach science as actually practiced for a better understanding of the dynamics of scientific progress (Niaz, 2011, p.7).

Item no. 2 deals with the importance of imagination in scientific research. It requires creativity to imagine a pattern to fit into the existing framework or go beyond to explain the problem. It helps in solving the big jigsaw puzzle. The findings reveal that majority of students (54% college and 84% school) acknowledges the use of imagination in the scientific research.

But there are substantial numbers of (53%) school students who think that imagination lacks reliability, whereas only 13% of college students think so. Also, there is ambiguity in the thought of school students as they take the position that imagination is the main source of innovation and is used more or less in scientific research and also agree with the position that imagination might become the tool for scientists to prove his point at all costs and also it lacks reliability (S9, S5; FGD). As per the suggestion to infer the views as explained above; these students possess naïve views about the role of imagination. The students were followed up in FGD.

The larger number of college students, recognizing the importance of imagination in science may come because of longer exposure to science and scientific practices as they study similar topics like atomic models, rules and principles to explain the nature of electron in much detail in graduation than in class XI. But this needs to be explored because even at this level majority of students think that imagination cannot be used in science; "it is the thing to be used in literature" (C6, C5: FGD). Around (26%) students are going for uncertain and neutral stance. This might reveal that they do not know the topic well and hence, playing safe by not being on either side of extremes to avoid being asked further. However, the researcher could not follow this pattern up afterwards to elicit the reasons from these students for being uncertain in many items due to time constraint.

Item no.3 deals with the tentative nature of scientific knowledge and starts with the statement- 'Even if the scientific investigations are carried out correctly, the theory proposed can still be disproved in the future.' There are 66% of college students, who disagree with the position that scientific research will face revolutionary change, and the old theory will be replaced; whereas 50% of school students agree with this position. Though the response cannot be considered naïve in either case; but it may point toward college students looking at the scientific progress as building up on the earlier theories and thus, looks in terms of evolutionary nature of scientific progress whereas school students seem to look at them as sudden fall of a 'well established theory' because of some anomalies and rise of a new theory to substitute the earlier one. Substantial section of college and school students goes for the position which talks about cumulative nature of scientific advances and hence the old theory is preserved. There are 53% of college and 56% of school students who think that with the accumulation of research data and information, the theory will evolve, finding additional and useful piece and clue about the problem and thus explaining it even better. The responses of students show that they have the idea about the tentative nature of scientific knowledge as in their textbook; they find the representation of various discoveries and scientific advances in a chronological manner, giving them the idea that scientific research does not remain static but constantly undergo certain changes and thus are tentative in nature. However, linkages among various theories and history of its development are not presented in the textbook (Chapter 3, section 3.1.2).

Item no.4 concerns with socio-cultural embeddedness of scientific knowledge and the statement is- Scientific investigations are influenced by socio-cultural beliefs and values present at a given time. The response of both the sample students indicates that they have held naïve views about this aspect which has significant role to play in the scientific knowledge. 60% of college students disagree and 33% of school students strongly disagree with the position that socio-cultural values influence the direction and topics of scientific investigations. They possess similar ideas for the position which says scientists are influenced by socio-cultural values and they disagree with this stance. 40% college and 33% school students strongly agree with the option that scientists with good training remain value free and thus do not get influenced by socio-cultural values and hence carry out neutral and objective research. 26% college and 72% school students think that science is an objective sphere and is contrary to the subjective socio-cultural values; so in scientific research, socio-cultural values and beliefs have no role to play. These are clearly the naïve views students have upheld. Only 6% of college and school students acknowledge that even scientists are social beings and that they cannot be context free and subjectivity will come into place while carrying out research. The root to these notions was required to be elicited from the students to know why and how they think about scientific activities, so the theme of the item (socio-cultural beliefs and values influence scientific investigations) was kept for FGD.

Item no.5 deals with theory laden nature of scientific knowledge and the statement is- Scientists' observations are influenced by their personal beliefs therefore; they may not make the same observations for the same experiment. 40% of college students disagree with the position that 'observations' will be different, because different beliefs lead to different expectations influencing the observation', however, only 16% of school students think the same. There are 63% of school students and only 26% of college students who agree with this position. This may appear that college students are more steeped into the thinking about science as objective reality only and no scope of any context and subjectivity remains on the part of scientists but good number of school students has informed view on this position. Again, this difference in the opinion of two groups needed to be explored so was kept for FGD with both the groups separately. 46% college and 33% school students hold naïve views in the position which says that observations will be the same, because scientists with training can keep aside personal values to conduct objective observations. 40% college and 57% school students have naïve views for the position as they agree with it which implies that observations are considered to be independent from theories. Also, Karl Popper puts it "all observations have a frame of reference and horizon of expectations" with necessary selectivity.

Item no. 6 deals with the myth of 'scientific method'. 53% of college students and 93% of school students hold naïve views as they agree with the position which states that the scientific method ensures valid, clear, logical and accurate results. Thus, most scientists follow the universal method in research. Again, 80% of college students and 93% of school students have naïve views as they think that most scientists use scientific method because it is a logical procedure; as if undermining other methods of research too as logical procedure. 57% school and 26% college students hold the naïve views as they think that the only method to verify the obtained results is scientific method.

Item no. 7 and 8 are not discussed here because we could not get consistent responses of students for these items. These items are related to the epistemological status of scientific knowledge. The items intended to understand students' position for invention and discovery and what they think of laws and theories in terms of these.

Item no. 9 deals with the understanding about law and theory amongst students.66% school students and 20% college students hold the naïve view as they agree with this statement that theories are not as definite as laws. However, 40% of college students have informed views in relation to 20% of school students. Substantial section of the sample students hold naïve views about the law and theory where they look upon a theory which can become laws on more supporting evidence and after standing to many tests. There were 93% of school students and 60% of college school students who think in this manner. Understanding about theory and laws in students was followed up in FGD.

The findings from VOSE are summarized in the following table:

Dimensions of NOS	Likert scale	Strongly Disagree	Disagree	% of disagreement	Neutral	Agree	Strongly Agree	% of Agree.
Tentativeness of scientific theory		2	4	13	5	25	9	76
Observation is theory laden		14	15	64	4	4	8	27
Diverse scientific methods		1	8	20	15	16	5	47
Theories and laws are invented		3	11	31	9	20	3	51
Theories and laws are different ideas		2	17	42	14	5	7	27
Use of imagination in science		2	4	13	11	12	16	62
Empirical evidences validate scientific knowledge		3	4	16	7	20	11	69
Subjectivity in science		4	11	33	4	6	20	61

The table reflects the thought profile of the sample group (combined college and school students). As indicated, majority of students (seventy six percent) recognized the tentativeness of scientific knowledge. However, few students (twenty seven percent) opted for theory laden nature of observation and hence influence in the research. Considerable number of students (sixty two percent) appreciates the use of imagination in scientific research. Forty six percent of students chose for the positions of diverse scientific methods.

Around twenty six percent held the position of laws and theories as different ideas and majority of them look at these as related hierarchically. Around half of the students think that theory and laws are invented. From the findings, it appears that some aspects of nature of science like tentativeness in science, imagination in science, need of diverse scientific methods in science are known to most of the students. But the aspects like subjectivity, theory laden nature of observation are not understood to them as appeared from their responses. They lay more emphasis on the empirical method of gaining scientific knowledge and thus undermining other means of generating scientific knowledge like observation, thought experiments. It was found in the NCERT that there is dearth of mention about the varied methods of scientific investigations used by different scientists to give various atomic models.

Students' Conception about 'Model' of the Atom:-

This part (Section B) of the questionnaire had used the concept of 'structure of the atom' to focus on the tentative, inferential, and developmental nature of the scientific knowledge.

The items in this section of the questionnaire were adapted from the teaching module developed by Dabas (2010) in her thesis to develop understanding about the NOS in the students who are studying these topics. The items in this section provided an opportunity to understand the students' conception of the atom which reflects their understanding about the nature of science. The ten item questionnaire (open-ended) helped elicit their intuitive ideas which showed that:

- About thirty three percent of school students believed that atoms were solid particles in response to item no-1. They listed different reasons like- atoms are always depicted as sphere and circles, having perfect shape in the science textbooks; they say "if they were not solid then how this structure would have been maintained and matter would have been compressible then how orbits and orbital electrons would remain in the atom" (S1: FGD). Another group of students was saying that everything in the universe is made up of atoms and these are building blocks of everything; if the atoms were not solid, then how the matter around us would have got fixed shape. One student wrote very differently that "light passes through liquids and gases, but we see that at a shortest and smallest place which is negligible the light cannot pass through which depicts its solid nature" (S6: FGD). What the student meant by this was followed up with and is discussed in section (4.3). Others gave reasons like-atoms have definite mass and occupy space; atoms are made up of neutron, proton, and electron with a nucleus at the centre so it should be solid. Ben-Zvi et al (cited in Driver et al (1994)) working with Israeli children found that pupils often regard atoms as 'small bits of solid' and it is widely accepted that this misconception persists even when they go to University. Around 20% college students held the similar notions that atom were solid particles because everything ultimately is solid and that is why after some extent they are incompressible and cannot be broken further.
- About forty six percent school students said that atoms were not solid particles as a liquid, and gases also have atoms. These students tend to think that 'solid particles' related only to the solid state of the matter. Some had the views like atoms appear like cloud which is not solid and it has lots of spaces in it. One student wrote, "Combination of atoms can be judged into solid, liquid and gases. A single atom cannot be judged into solid, liquid and gas. So, the classification of this sort is baseless" (S2: FGD). Similar types of views in students are reported in the research of Dabas (2010) like students think that if atoms were solid, then they could not have existed freely in the nature. Clearly, there is much more that needs to be understood about students' conception related to atoms and states of matter.
- 70% of college students say they do not agree with atoms as solid particles and they also listed the similar reasons as that of school students for explaining why they think so. Some say, because we see penetrable material around us which means atoms are not only solid particles. Again, what do they understand about the nature of constituents of solid, liquid and gas need to be understood. One student wrote "atoms appear wavelike so they must be made up of wave like things" (C4: FGD). This view might have come from the representation they find in the books without explaining in an engaging manner.

- Scientists now have a complete understanding of the atom (statement 2). 28% of school students held the view that we have complete understanding of the atom as we have well developed quantum mechanical models which explain most of the properties, when probed further, they could not explain what type of properties are those which earlier theories could not explain but the quantum mechanical model can explain. It appears that they may have crammed what heard from teachers and read in the books only as information without understanding it. But most of the students disagree with it and give reasons like, what we know today changes tomorrow with advancement in technology, researches are still going on to know more about the atom and its structure. Still conclusively we cannot say that we know accurately and completely about atoms. Many said that we still doubt whether entity called atom exists or not. We know more than our earlier times but should not become complacent about it. College students also had similar views to share, but the difference in the reasons they were giving like- one student said "we have complete understanding about the atom because then only we are able to study the properties of elements as they are made up of atoms so we have to know them before" (C1: FGD). Another group of college students says that knowledge construction and development is an ongoing and dynamic process.
- Atoms are mainly composed of empty spaces. Around 45% school students agreed with this statement. They related this to the Rutherford's experiment which showed lots of alpha rays passing through gold foil straight. Some also related this to Bohr model which talks about discrete orbits and shells like-K, L, M, N etc. and the rest being the empty spaces in between. College students also believed that atoms have empty spaces and gave reasons because we know about the Rutherford's alpha scattering experiment.
- In the response to the question where they were asked to draw the structure of the atom; most of the school students (80 percent) used the analogy to the solar system and drew accordingly nucleus at centre and electrons revolving around it as they understood of Rutherford's nuclear model. In spite of having studied more advanced models to elucidate the structure of atom viz. Quantum mechanical model; they were using this model. On probing further, it was found that students could retain it because of its simple appearance and easiness. However, most of the college students tried to depict the atom according to the quantum model which gives a probabilistic picture of finding the electrons.
- In response to item no.5 which says that since scientists cannot see inside of an atom, it is not possible to believe any of these models. About 45% of school and 30% of college students indicated that scientists had seen the inside of the atom. Some thought that with the help of modern technology like STM (Scanning Tunneling Microscope) etc. we can see the interior of the atoms. They had no clue that the models need not be always representing the physical reality, but could also be based on interpretations. They also had no idea about the difference between inference and observation though they use these terms in their practical classes. Some were not sure about imagination explaining the real phenomena. Similar types of views have also been expressed in other researches (Bent, 1984; Dabas, 2010).

Such students appeared to possess a naïve epistemological view of scientific knowledge (Nadeau and Desautels, 1984). They viewed the structure of the atom as copy of reality, rather than as the constructed representations that embodied certain theoretical perspectives. The most common rationale for students' explanations of the change in science was attributed to better equipment or technology.

When asked about examples of a model; about seventy percent listed the models like that of a heart, skeleton, windmill, eye, etc. Majority of the students were having the idea about models as a working model as they are in the habit of using the term without knowing the difference between mental and physical models. All these examples indicated that students had understood model as a three dimensional picture and a proven fact (Lederman and O' Malley, 1990).

Discussion:-

The primary aim of this study was to understand the students' views on the nature of science and the role played by the NCERT chemistry textbook in developing this understanding in them. In this study, it was attempted to understand what are students' understandings and perception towards the nature of science and science processes.

Scientific content, processes and the nature of science overlap and interact in significant ways and all are important for students to learn. For example, observing and inferring is a scientific process. On the other hand, an understanding that observations are constrained by our perceptions and are inherently theory-laden is part of an understanding of the nature of science. The tentativeness of scientific knowledge is not limited to the recognition that scientific knowledge has changed through history. Rather, science draws its tentative and revisionary characteristics of the development of theories and the limitations imposed on ways of knowing. We present the conclusions of the current research in this section as follows:

The review of the NCERT chemistry textbook reflects that historical and philosophical treatment which is required for better understanding of the topic 'structure of the atom' is not included in the text (Appendix 1 and section 3.2.2). Also this affects students' content knowledge of the topic as was found in this study that majority of participants had weak content knowledge.

Students' views on various dimensions of the nature of science were identified using the VOSTS and VOSE questionnaires. Also, students' understanding about models of the 'structure of the atom' was probed as part of the nature of science by using the teaching module designed by Dabas (2010).

Over one third of the students held the naïve view that scientific knowledge, including theories and laws does not change but is final and fixed and static as seen from the VOSE questionnaire (Item no.3). The FGD with college and school students revealed that they understood that the scientific concept like the 'structure of the atom' changes in the light of new experiments. About two thirds of students recognized that scientific knowledge is not absolute and final but tentative in nature. It was also observed that an understanding of the role of imagination in science blend of inference and observation required to reach a scientific concept could be developed in students provided the scope for discussion with them is there. As was seen in this study during focus group discussions the students who earlier said that scientific knowledge is more reliable if it is proven empirically later on came to the point that the role of inference in scientific results are also very important because not everything in the universe can be seen or observed. We have to do thought experiments and infer on the basis of some premises (Thomson's plum pudding model) as in the case of the 'structure of the atom'. This modification in their perception came about after the 'tricky track activity' developed by Lederman was performed with students.

Students could make out that some events are explained on the basis of inference because there may be the possibility that no one was present at the time when the event had happened.

Students had some understanding about the tentative nature of scientific knowledge as they gave reasons like better equipment lead to improved observations which may modify or add to the existing knowledge thus scientific knowledge is never final. Fifty five percent of school and thirty percent of college students held the naïve view about ‘atom and its structure’. As they seemed to believe that for scientists to know and be sure about the structure of the atom they have to see them. Scientists cannot be certain unless they ‘see’ the atoms or anything else they want to investigate.

Concerning the cultural and social aspects of scientific knowledge students initially felt that scientists and their research remain uninfluenced by this aspect, but during FGD they could understand that same phenomena like that of biofuels or GM foods can be investigated differently by different scientists belonging to different social and cultural contexts. They recognized that research priorities are determined by the need of the country so developed and developing countries would look upon the problems differently.

In the VOSTS over fifty percent of college and sixty percent of school students held the naïve view that models are copies of reality (section 4.3 statement 1). While discussing with students during FGD this was revealed that students could recognize that models which explain ‘structure of the atom’ are the mental representation and a guess based on experimental results (Section 5.2; FGD). However, in the theme of ‘scientific method’ there were very few students at both the levels who think that scientific knowledge not necessarily develop by following ‘scientific method’ only but it may arise by chance imagination etc. also. Others thought that in any situation scientific knowledge to develop; firstly, they have to encounter the problem and then other steps have to be followed which we call scientific method. They seem to undermine the role of creativity, imagination and the open mindedness of scientists. This persistence may be attributed to the strong influence of school textbooks and other materials which conjecture events of chance and serendipity as part of the process of discovery.

Students at both the levels held misconceptions about theories, laws and hypotheses. For them all three concepts are related hierarchically on the basis of supporting evidence in a progressive manner, i.e. hypothesis becomes theory and theory becomes law on accumulation of more supporting evidence.

It was observed during interaction with students of grade 11 that those students who had availed congenial environment at home i.e. where discussion about science content about scientists, etc. (with the help of family members like parents, elder brother etc.) takes place had comparatively better understanding about the nature of science. These students held informed views on certain dimensions of nature of science pertaining to theory laden nature of the observation role of imagination in science, social and cultural embeddedness of scientific knowledge tentativeness in science and so on in comparison with other students who had no one at home or outside to discuss with about such issues.

During FGD it was observed that students were able to better relate to the discovery of atom various events which had taken place in explaining about the structure of atom on being provided with a teaching module (Dabas 2010) to read. This step was not the primary focus of the research, but was done in a cursory way to understand how some enriching sources could help them develop a better understanding of the nature of science. Positive remarks from students at both the levels came. They found it interesting because the development of ‘atom and its structure’ was written with the mention about the contexts in which the theories or models were given with links among various discoveries in this particular area. The narrative was written with the inclusion of history and philosophy of science which got students interested in understanding the journey ‘atom’ travelled to come in its present form.

Then school students were asked to express how they would want this topic ‘structure of the atom’ to be written in the NCERT chemistry textbook many had written language that should be made simpler and commonly used. In a way, their writings implied that technical and jargonized language in the textbook complicates the flow of understanding of the scientific concepts. However, we did not analyse the textbook on these lines. This step was taken up as a suggestion from those for whom we want the textbooks to be written. They had also pointed that coherence should be there throughout the chapter because new topic starts without any link with the earlier topics which create confusion and understanding is not built and we are forced to cram this information to pass examination.

Implications:-

The science education and scientific researches call for special attention on science education right from earlier classes. So, that students may be able to relate to scientific concepts better in its entirety from beginning. The textbook has a great role to play because students and teachers use it as the main book and rely on them heavily. Bodies like the NCERT could make an effort to write the science textbook at senior secondary level in such a way that students better relate to the concepts taught. It may help them to develop interests to continue further in scientific research. This could be possible only when their understanding about the NOS is strong. FGD gives a ray of hope that if discussion in the classroom includes the aspects of the nature of science may enhance knowledge of the science and about the science.

Science education aims at preparing individuals to have a better understanding of the world. This may enable them to take responsible decisions to appreciate the natural world help in its protection and respond towards changing technology sensibly. This may also encourage them to learn the science processes to understand and analyze situations. Therefore, it is necessary to design textbooks with more explicit representation of aspects which develop understanding about the nature of science in students. This study also recommends the need to design textbook according to the frameworks of HPS for ‘structure of the atom’ and Lederman pertaining to the NOS in the whole textbook.

It is noteworthy that the NCERT could aid in the proper incorporation of the nature of science in curriculum. It could also train the teachers to support pedagogical methods where they provide learners to engage in actual processes of science. The understanding of the nature of science is important in creating and reviving interest in science in addition to the work of scientists. Since knowing about the ways the theories are developed may better help them understand process of science.

The relevant and fruitful activities and situations should be provided to students to allow them to challenge their conception about various aspects of the nature of science. Projects and home assignments may be given to students, which require the use of aspects of the nature of science and science processes. For example, types of questions that are raised in the teaching modules developed by Dabas (2010) such as - Controversies in science and the media over genetically modified food Is there one scientific method scientists and the language they use, etc. If students are exposed to these types of debates requiring their own explanation and ideas may likely improve their understanding about science.

The topic 'structure of the atom' has wide scope to convey the philosophical, historical epistemological and psychological aspects of the nature of science to the students. The curriculum designers and textbook writers could think about incorporating chance and serendipity. These could be emphasized as one of the processes of discovery of scientific knowledge with more elaboration. It has been seen that one or two brief examples in the textbooks may not be effective in steering the naïve views about discovery in students away. As other researches also claim that the change in students' views on the nature of science is a difficult process and take place gradually and progressively (Driver et al 1996).

Conclusion:-

This study is exploratory in nature and has found that there is a need to develop interesting and engaging reading materials for better content development of students as well as for developing an understanding about the nature of science in them. Also, the current examination system may need a redress to revisit what it purports to test amongst students. What does it emphasize on (understanding about the process of science, nature of science or merely seeking/ justifying mugging up some concepts to pass the exam)? Is the current practice of examination system able to create scientifically literate citizens? All these questions arise because they serve a better guide to those who are science educationists, policy makers, researchers so that immediate and collective steps may be raised with the collective benefit of our young learners of science, to make our citizens scientifically literate and most of it can be achieved when there is an emphasis from all sources of education to develop an understanding of the nature of science amongst students.

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Annexure 1

Criteria Chosen for a Review of the NCERT textbook

Thomson Model

T1- cathode rays are charged particles or waves in the ether.

T2- Determination of m/e ratio to decide whether the cathode rays were ions or a universal charged particle.

Rutherford Model

R1- Nuclear atom

R2- Probability of large deflections is exceedingly small, as the atom is the seat of an intense electric field.

R3- single/ compound scattering of alpha particles.

Bohr's Model

B1- Paradoxical stability of the Rutherford model of the atom.

B2- explanation of the hydrogen line spectrum

B3- Deep philosophical chasm. Bohr's incorporation of Planck's 'quantum of action' to the classical electrodynamics of Maxwell represented a strange 'mixture' for many of Bohr's contemporaries and philosophers of science. This episode illustrates how scientists, when faced with difficulties, often resort to such contradictory 'grafts.'

Quantum Mechanical Model

Q- Heisenberg's gamma ray microscope: It emphasizes on the significance of thought experiment in scientific research in situations where laboratory setup is not feasible. This criteria was developed by Malhotra (2010).

Q1- Origin of the quantum hypothesis

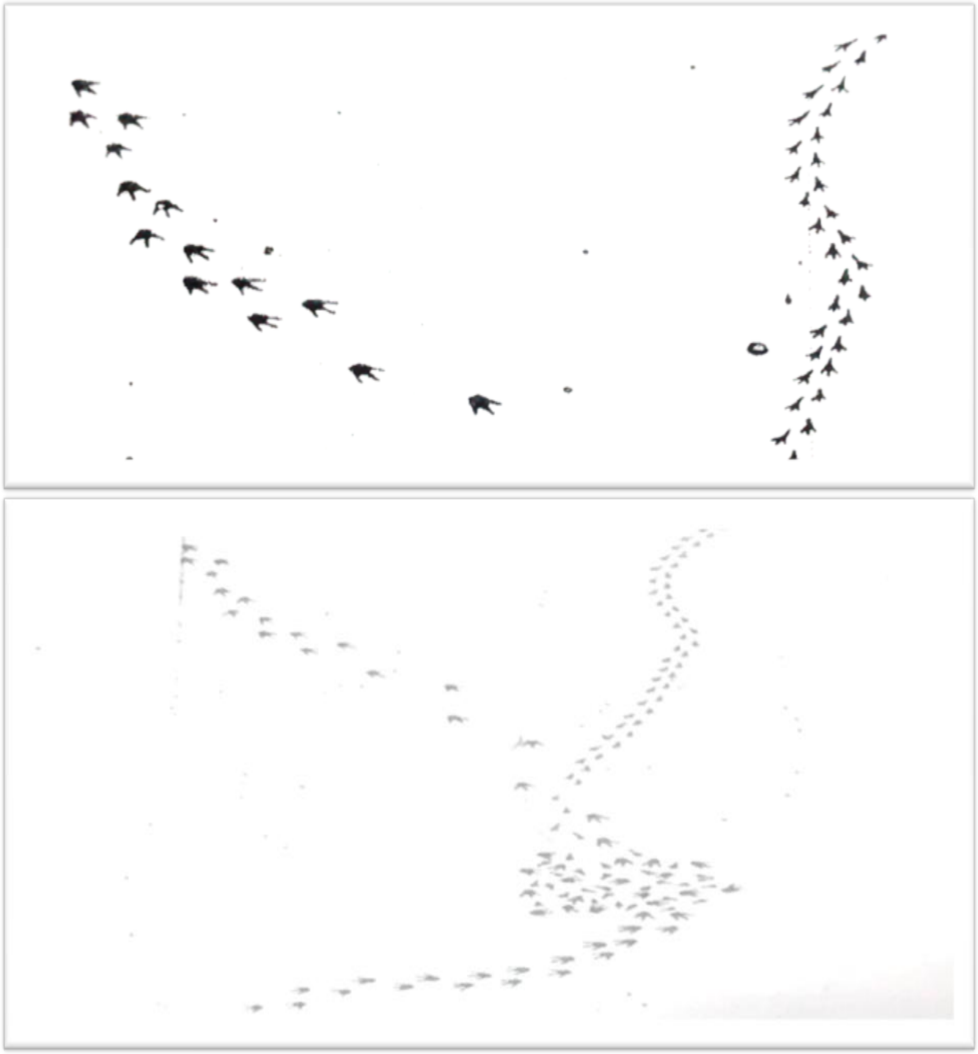
Q3- Differentiation between an orbital & electron density.

Q4- differentiation and comparison between classical and quantum mechanics.

Q5- Introduction of quantum numbers based on electron density.

Annexure 2

Pictures shown to participants to perform 'Tricky Track Activity'



Picture 1:- (above) and 2 (below)

Annexure 3
Questionnaire used for Understanding Students' Views on the Nature of Science

Section–A (I)
Instructions to participants: Each item of this questionnaire starts with a statement about the nature of science. You may strongly agree (SA) with it, strongly disagree (SD) with it, or have other thoughts about it. Each statement is followed by several responses. Please read all the responses first, then circle your opinion on the right side (SD, D, U, A, SA) of each response according to ***your*** knowledge of how scientists work and science develops. There is no right or wrong answer. Thank you.
Note:
SD= Strongly Disagree
D = Disagree
U = Uncertain or No Comment

A = Agree
SA= Strongly Agree

1. When two different theories arise to explain the same phenomenon (e.g. the nature of electron), scientists will accept the two theories at the same time.
A. Yes, because scientists still cannot objectively tell which one is better; therefore, they will accept both tentatively.
SD D U A SA
B. Yes, because the two theories may provide explanations from different perspectives, there is no right or wrong.
SD D U A SA
C. No, because scientists tend to accept the theory they are more familiar with. SD D U A SA
D. No, because scientists tend to accept the simpler theories and avoid complex theories. SD D U A SA
E. No, the academic status of the person who proposed the theory will influence other scientists' acceptance of the theory. SD D U A SA
F. No, scientists tend to accept new theories which deviate less from the current core scientific theory.
SD D U A SA
G. No, scientists use intuition to make judgments. SD D U A SA
H. No, because there is only one truth, scientists will not accept any theory before distinguishing which is best.
SD D U A SA

2. While scientists are conducting scientific research, they also use their imagination.
A. Yes, imagination is the main source of innovation. SD D U A SA
B. Yes, scientists use their imagination more or less in scientific research. SD D U A SA
C. No, imagination is not consistent with the logical principles of science. SD D U A SA
D. No, imagination may become a means for a scientist to prove his point at all costs. SD D U A SA
E. No, imagination lacks reliability. SD D U A SA

3. Even if the scientific investigations are carried out correctly, the theory proposed can still be disproved in the future.
A. Scientific research will face revolutionary change, and the old theory will be replaced. SD D U A SA

B. Scientific advances cannot be made in a short time. It is through a cumulative process; therefore, the old theory is preserved.
SD D U A SA

C. With the accumulation of research data and information, the theory will evolve more accurately and completely, not being disproved.
SD D U A SA

4. Scientific investigations are influenced by socio-cultural beliefs and values present at a given time (e.g., religious beliefs, social bias about gender, caste, class etc.).

A. Yes, socio-cultural values influence the direction and topics of scientific investigations. SD D U A SA

B. Yes, because scientists participating in scientific investigations are influenced by socio-cultural values.
SD D U A SA

C. No, scientists with good training will remain value-free (neutral) when carrying out research.
SD D U A SA

D. No, because science requires objectivity, which is contrary to the subjective socio-cultural values.
SD D U A SA

5. Scientists' observations are influenced by their personal beliefs (e.g., personal experiences, presumptions) therefore; they may not make the same observations for the same experiment.

A. Observations will be different, because different beliefs lead to different expectations influencing the observation.
SD D U A SA

B. Observations will be the same, because the scientists trained in the same field hold similar ideas.
SD D U A SA

C. Observations will be the same, because through scientific training scientists can keep aside personal values to conduct objective observations.
SD D U A SA

D. Observations will be the same, because observations are exactly what we see and nothing more. Facts are facts. Interpretations may be different from one person to another, but observations should be the same.
SD D U A SA

E. Observations will be the same. Although subjectivity cannot be completely avoided in observation, scientists use different methods to verify the results and improve objectivity.
SD D U A SA

6. Most scientists follow the universal scientific method, step-by-step, to do their research (i.e., state a hypothesis, design an experiment, collect data, and draw conclusions).

A. The scientific method ensures valid, clear, logical and accurate results. Thus, most scientists follow the universal method in research. SD D U A SA

B. Most scientists use the scientific method because it is a logical procedure. SD D U A SA

C. The scientific method is useful in most instances, but it does not ensure results; therefore, scientists invent new methods. SD D U A SA

D. There is no so-called the scientific method. Scientists use any methods to obtain results. SD D U A SA

E. There is no fixed scientific method; scientific knowledge could be accidentally discovered. SD D U A SA

F. No matter how the results are obtained, scientists use the scientific method to verify it. SD D U A SA

7. Is scientific theory (e.g. atomic theory) "discovered" or "invented" by scientists from the natural world?

A. Discovered, because the idea was there all the time to be uncovered. SD D U A SA

B. Discovered, because it is based on experimental facts. SD D U A SA

C. Some scientists discover a theory accidentally, but other scientists may invent a theory from their known facts. SD D U A SA

D. Invented, because a theory is an interpretation of experimental facts, and experimental facts are discovered by scientists. SD D U A SA

E. Invented, because a theory is created or worked out by scientists. SD D U A SA

F. Invented, because a theory can be disproved. SD D U A SA

8. Is scientific law (e.g., gravitational law) "discovered" or "invented" by scientists from the natural world?

A. Discovered, because scientific laws are out there in nature, and scientists just have to find them. SD D U A SA

B. Discovered, because scientific laws are based on experimental facts. SD D U A SA

C. Some scientists discover a law accidentally, but other scientists may invent a law from their known facts. SD D U A SA

D. Invented, because scientists invent scientific laws to interpret discovered experimental facts. SD D U A SA

E. Invented, since there are no absolutes in nature, therefore, the law is invented by scientists. SD D U A SA

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9. In comparison to laws, theories have less evidence to support them.
A. Yes, theories are not as definite as laws. SD D U A SA
B. Yes, if a theory stands up to many tests it will eventually become a law; therefore a law has more supporting evidence. SD D U A SA
C. Not quite, some theories have more supporting evidence than some laws. SD D U A SA
D. No, theories and laws are different types of ideas. They cannot be compared. SD D U A SA

Section-A (II)
Instruction to participants:
Read the statement carefully-Think to yourself whether you agree or disagree with the statement or can't make up your mind. Then read the list of different positions on the topic. Pick the one that comes closest to your own positions.
Every statement ends with the same three positions. Here is how you can use them if you wish:
X. "I don't understand." This choice is included in case there is a key word or phrase that you just don't understand.
Y. "I don't know enough about this subject to make a choice".
Z. "None of these choices fit my basic viewpoint." This choice can be used when none of the other positions comes close to your own belief, or when you want to combine two or more choices into one position.
There are no "right" answers; this is not a test. We simply want to understand what your view or position is on a number of issues about science and how scientists work. Thank You.

1. Many scientific models used in research laboratories (such as the model of heat, the neuron, DNA, or the atom) are copies of reality.

Your position basically is :**(Please read from A to J, and then choose one.)**

Scientific models ARE copies of reality:
A. Because scientists say they are true, so they must be true.
B. Because much scientific evidence has proven them true.
C. Because they are true to life. Their purpose is to show us reality or teach us something about it.
D. Scientific models come close to being copies of reality, because they are based on scientific observations and research.

Scientific models are NOT copies of reality:
E. Because they are simply helpful for learning and explaining, within their limitations.
F. Because they change with time and with the state of our knowledge, like theories do.

G. Because these models must be ideas or educated guesses, since you can't actually see the real thing.
H. I don't understand.
I. I don't know enough about this subject to make a choice.
J. None of these choices fits my basic viewpoint.

2. When scientists classify something (for example, a plant according to its species, an element according to the periodic table, energy according to its source, or a star according to its size), scientists are classifying nature according to the way nature really is; any other way would simply be wrong.

Your position basically is. **(Please read from A to I, and then choose one.)**

A. Classifications match the way nature really is, since scientists have proven them over many years of work.
B. Classifications match the way nature really is, since scientists use observable characteristics when they classify.
C. Scientists classify nature in the most simple and logical way, but their way isn't necessarily the only way.
D. There are many ways to classify nature, but agreeing on one universal system allows scientists to avoid confusion in their work.
E. There could be other correct ways to classify nature, because science is liable to change and new discoveries may lead to different classifications.
F. Nobody knows the way nature really is. Scientists classify nature according to their perceptions or theories. Science is never exact, and nature is so diverse. Thus, scientists could correctly use more than one classification scheme.
G. I don't understand.
H. I don't know enough about this subject to make a choice.
I. None of these choices fits my basic viewpoint.

3. When developing new theories or laws, scientists need to make certain assumptions about nature (for example, matter is made up of atoms). These assumptions must be true in order for science to progress properly.

Your position basically is: **(Please read from A to I, and then choose one.)**

Assumptions MUST be true in order for science to progress:
A. Because correct assumptions are needed for correct theories and laws. Otherwise scientists would waste a lot of time and effort using wrong theories and laws.
B. Otherwise society would have serious problems, such as inadequate technology and dangerous chemicals.
C. Because scientists do research to prove their assumptions true before going on with their work.
D. It depends. Sometimes science needs true assumptions in order to progress. But sometimes history has shown that great discoveries have been made by disproving a theory and learning from its false assumptions.

E. It doesn't matter. Scientists have to make assumptions, true or not, in order to get started on a project. F. Scientists do not make assumptions. They research an idea to find out if the idea is true. They don't assume it is true.
G. I don't understand.
H. I don't know enough about this subject to make a choice.
I. None of these choices fits my basic viewpoint.

4. When scientists investigate, it is said that they follow the scientific method. The scientific method is:

Your position basically is: **(Please read from A to M, and then choose one.)**
A. The lab procedures or techniques; often written in a book or journal, and usually by a scientist.
B. Recording your results carefully.
C. Controlling experimental variables carefully, leaving no room for interpretation.
D. Getting facts, theories or hypotheses efficiently.
E. Testing and retesting proving something true or false in a valid way.
F. Postulating a theory then creating an experiment to prove it.
G. Questioning, hypothesizing, collecting data and concluding.
H. A logical and widely accepted approach to problem solving.
I. An attitude that guides scientists in their work.
J. Considering what scientists actually do, there really is no such thing as the scientific method.
K. I don't understand.
L. I don't know enough about this subject to make a choice.
M. None of these choices fits my basic viewpoint.
5. The best scientists are those who follow the steps of the scientific method.

Your position basically is: (**Please read from A to H, and then choose one.)**

A. The scientific method ensures valid, clear, logical and accurate results. Thus, most scientists will follow the steps of the scientific method.
B. The scientific method should work well for most scientists; based on what we learned in school.
C. The scientific method is useful in many instances, but it does not ensure results. Thus, the best scientists will also use originality and creativity.
D. The best scientists are those who use any method that might get favorable results (including the method of imagination and creativity).
E. Many scientific discoveries were made by accident, and not by sticking to the scientific method.
F. I don't understand.
G. I don't know enough about this subject to make a choice.
H. None of these choices fits my basic viewpoint.

6. Scientific discoveries occur as a result of a series of investigations, each one building on an earlier one, and each one leading logically to the next one, until the discovery is made.

Your position basically is: (**Please read from A to J, and then choose one**.)

Scientific discoveries result from a logical series of investigations:
A. Because experiments (for example, the experiments that led to the model of the atom, or discoveries about cancer) are like laying bricks onto a wall.
B. Because research begins by checking the results of an earlier experiment to see if it is true. A new experiment will be checked by the people who come afterwards.
C. Usually scientific discoveries result from a logical series of investigations. But science is not completely logical. There is an element of trial and error, hit and miss, in the process.
D. Some scientific discoveries are accidental, or they are the unpredicted product of the actual intention of the scientist. However, more discoveries result from a series of investigations building logically one upon the other.
E. Most scientific discoveries are accidental, or they are the unpredicted product of the actual intention of the scientist. Some discoveries result from a series of investigations building logically one upon the other.

Scientific discoveries do not occur as a result of a logical series of investigations:
F. Because discoveries often result from the piecing together of previously unrelated bits of information.
G. Because discoveries occur as a result of a wide variety of studies which originally had nothing to do with each other, but which turned out to relate to each other in unpredictable ways.
H. I don't understand.
I. I don't know enough about this subject to make a choice.
J. None of these choices fits my basic viewpoint.

7. Scientists publish the results of their work in scientific journals. When scientists write an article for a journal, they organize their report in a very logical orderly way. However, scientists actually do the work in a much less logical way.

Your position basically is :**(Please read from A to J, and then choose one.)**

Articles are written in a more logical way than the actual work:
A. Because scientists can think and work without following a set plan. Consequently, if you read the actual order of their thoughts and procedures, it would be confusing. Therefore, scientists write logically so other scientists will understand the results.
B. Because scientific hypotheses are personal views or guesses and thus are not logical. Scientists, therefore, write logically so other scientists will understand the results.
C. Scientists usually don't want to give away "the recipe" but they do want to tell the world about their results. So they write it up logically but in a way that does not reveal how it was actually done.
D. It depends. Sometimes scientific discoveries happen by accident. But other times discoveries happen in a logical orderly way, just like the articles are written.

Articles are written in a logical way showing how the actual work was done:
E. Because a scientist's work is conducted logically; otherwise, it would not be useful to science and technology.

F. Because scientists do work in a logical way so that their published report will be easier to write in a logical way.
G. Articles are not necessarily written in a logical way. They're written the way the work was done. This can be complicated or straightforward.
H. I don't understand.
I. I don't know enough about this subject to make a choice.
J. None of these choices fits my basic viewpoint.

8. Scientists should NOT make errors in their work because these errors slow the advance of science.

Your position basically is :**(Please read from A to H, and then choose one.)**

A. Errors slow the advance of science. Misleading information can lead to false conclusions. If scientists don't immediately correct the errors in their results, then science is not advancing.
B. Errors slow the advance of science. New technology and equipment reduce errors by improving accuracy and so science will advance faster.

Errors CANNOT be avoided:
C. So scientists reduce errors by checking each others' results until agreement is reached.
D. Some errors can slow the advance of science, but other errors can lead to a new discovery or breakthrough. If scientists learn from their errors and correct them, science will advance.
E. Errors most often help the advance of science. Science advances by detecting and correcting the errors of the past.
F. I don't understand.
G. I don't know enough about this subject to make a choice.
H. None of these choices fits my basic viewpoint.

9. Even when making predictions based on accurate knowledge, scientists can tell us only what probably might happen. They cannot tell what will happen for certain.

Your position basically is: (**Please read from A to H, and then choose one**.)

Predictions are NEVER certain:
A. Because there is always room for error and unforeseen events which will affect a result. No one can predict the future for certain.
B. Because accurate knowledge changes as new discoveries are made, and therefore predictions will always change.
C. Because a prediction is not a statement of fact. It is an educated guess.
D. Because scientists never have all the facts. Some data are always missing.
E. It depends. Predictions are certain, only as long as there is accurate knowledge and enough information.
F. I don't understand.
G. I don't know enough about this subject to make a choice.
H. None of these choices fits my basic viewpoint.

10. Scientists in different fields look at the same thing from very different points of view (for example, H+ causes chemists to think of acidity and physicists to think of protons). This makes it difficult for scientists in different fields to understand each others' work.

Your position basically is: (**Please read from A to H, and then choose one**.)

It is difficult for scientists in different fields to understand each other:

A. Because scientific ideas depend on the scientist's viewpoint or on what the scientist is used to.
B. Because scientists must make an effort to understand the language of other fields which overlap with their own field. It is fairly easy for scientists in different fields to understand each other:
C. Because scientists are intelligent and so they can find ways to learn the different languages and points of view of another field.
D. Because they have likely studied the various fields at one time.
E. Because scientific ideas overlap from field to field. Facts are facts no matter what the scientific field is.
F. I don't understand.
G. I don't know enough about this topic to make a choice.
H. None of these choices fits my basic viewpoint

Section-B

Guidelines for students: There are statements given about the structure of the atom. Please go through these statements carefully and give your response. Remember, this is to know about your views and understanding**; it is not a test.**

Do you agree or disagree with the following statements (1-3, 5-6). Explain giving reasons why you think so.

1. Atoms are solid particles.

2. Scientists now have a complete understanding of the atom.

3. Atoms are composed mainly of empty space.

4. You have heard about different scientists giving a model of the atomic structure. What do you think a model is?

5. Since scientists cannot actually see inside the atom, it is not possible to believe any model of the atom that has been given.

6. Early models of the atom were useless theories, which were eventually discarded.

____
____
____
____
____
____
____
____

7. What does an atom look like? Describe in your words.

The atoms looks like____

8. How do you know that atoms look like what you have described?
Because,____

9. Why do you need to study different models of atomic structure?

10. Which model according to you can best explain the structure of the atom? Why do you think so?

Annexure 4
Responses of Students (College and School) on the Nature of Science Questionnaire: VOSE Represented in a tabular form separately for Both the Participating Groups

Item no. 1

1. When two different theories arise to explain the same phenomenon (e.g. the nature of electron), scientists will accept the two theories at the same time.					
A. Yes, because scientists still cannot objectively tell which one is better; therefore, they will accept both tentatively.	SD (5) C S 1 4	D (9) C S 4 5	U (4) C S 2 2	A (22) C S 6 16	SA (5) C S 2 3
B. Yes, because the two theories may provide explanations from different perspectives, there is no right or wrong.	SD (4) C S 1 3	D (4) C S 1 3	U (3) C S 1 2	A (31) C S 10 21	SA (3) C S 1 2
C. No, because scientists tend to accept the theory they are more familiar with.	SD (19) C S 6 13	D (12) C S 4 8	U (8) C S 1 7	A (4) C S 2 2	SA (2) C S 2 0
D. No, because scientists tend to accept the simpler theories and avoid complex theories	SD (21) C S 10 11	D (13) C S 1 12	U (5) C S 2 3	A (4) C S 2 2	SA (2) C S 0 2
E. No, the academic status of the person who proposed the theory will influence other scientists' acceptance of the theory.	SD (19) C S 4 15	D (15) C S 6 9	U (5) C S 2 3	A (4) C S 2 2	SA (2) C S 1 1
F. No, scientists tend to accept new theories which deviate less from the current core scientific theory.	SD (5) C S 2 3	D (13) C S 2 11	U (11) C S 4 7	A (12) C S 2 10	SA (4) C S 4 0
G. No, scientists use intuition to make judgments.	SD (6) C S 2 4	D (14) C S 4 10	U (11) C S 3 8	A (9) C S 2 7	SA (5) C S 4 1
H. No, because there is only one truth, scientists will not accept any theory before distinguishing which is best.	SD (7) C S 3 4	D (7) C S 2 5	U (4) C S 2 2	A (14) C S 4 10	SA (13) C S 4 9

Item no. 2

2. While scientists are conducting scientific research, they also use their imagination.					
A. Yes, imagination is the main source of innovation.	SD (0) C S 0 0	D (1) C S 0 1	U (3) C S 3 0	S (16) C S 8 8	SA (25) C S 4 21

B. Yes, scientists use their imagination more or less in scientific research.	SD (2) C S 0 2	D (4) C S 0 4	U (11) C S 3 8	S (13) C S 1 12	SA (6) C S 2 4
C. No, imagination is not consistent with the logical principles of science.	SD (2) C S 1 1	D (13) C S 2 11	U (12) C S 3 9	S (6) C S 0 6	SA (3) C S 0 3
D. No, imagination may become a means for a scientist to prove his point at all costs.	SD (13) C S 10 3	D (11) C S 1 10	U (6) C S 2 4	S (15) C S 2 13	SA (0) C S 0 0
E. No, imagination lacks reliability.	SD (8) C S 6 2	D (7) C S 1 6	U (12) C S 6 6	S (16) C S 2 14	SA (2) C S 0 2

Item no. 3

3. Even if the scientific investigations are carried out correctly, the theory proposed can still be disproved in the future.					
A. Scientific research will face revolutionary change, and the old theory will be replaced.	SD (3) C S 1 2	D (14) C S 10 4	U (7) C S 6 1	S (17) C S 2 15	SA (4) C S 2 2
B. Scientific advances cannot be made in a short time. It is through a cumulative process; therefore, the old theory is preserved	SD (4) C S 2 2	D (4) C S 1 3	U (12) C S 4 8	S (19) C S 2 17	SA (6) C S 2 4
C. With the accumulation of research data and information, the theory will evolve more accurately and completely, not being disproved.	SD (2) C S 1 1	D (4) C S 2 2	U (5) C S 2 3	S (25) C S 8 17	SA (9) C S 2 7

Item no. 4

4. Scientific investigations are influenced by socio-cultural beliefs and values present at a given time (e.g. religious beliefs, social bias about gender, caste, class etc.).					
A. Yes, socio-cultural values influence the direction and topics of scientific investigations.	SD (14) C S 4 10	D (15) C S 9 6	U (4) C S 2 2	S (4) C S 2 2	SA (8) C S 1 7
B. Yes, because scientists participating in scientific investigations are influenced by socio-cultural values.	SD (11) C S 6 5	D (18) C S 4 14	U (8) C S 2 6	S (5) C S 2 3	SA (3) C S 1 2
C. No, scientists with good training will remain value free (neutral) when carrying out research.	SD (2) C S 1 1	D (6) C S 2 4	U (6) C S 2 4	S (15) C S 4 11	SA (16) C S 6 10
D. No, because science requires objectivity, which is contrary to the subjective socio-cultural values.	SD (1) C S 1 0	D (4) C S 2 2	U (14) C S 8 6	S (22) C S 4 18	SA (4) C S 0 4

Item no. 5

5. Scientists' observations are influenced by their personal beliefs (e.g. personal experiences, presumptions) therefore; they may not make the same observations for the same experiment.					
A. Observations will be different, because different beliefs lead to different expectations influencing the observation	SD (4) C S 1 3	D (11) C S 6 5	U (4) C S 2 2	A (23) C S 4 19	SA (3) C S 2 1
B. Observations will be the same, because the scientists trained in the same field hold similar ideas.	SD (5) C S 4 1	D (23) C S 4 19	U (8) C S 4 4	A (8) C S 2 6	SA (1) C S 1 0
C. Observations will be the same, because through scientific training scientists can keep aside personal values to conduct objective observations	SD (4) C S 2 2	D (12) C S 4 8	U (12) C S 2 10	A (12) C S 3 9	SA (5) C S 4 1
D. Observations will be the same, because observations are exactly what we see and nothing more. Facts are facts. Interpretations may be different from one person to another, but observations should be the same.	SD (3) C S 0 3	D (4) C S 1 3	U (15) C S 8 7	A (19) C S 4 15	SA (4) C S 2 2
E. Observations will be the same. Although subjectivity cannot be completely avoided in observation, scientists use different methods to verify the results and improve objectivity.	SD (2) C S 2 0	D (4) C S 2 2	U (5) C S 1 4	A (23) C S 6 17	SA (11) C S 4 7

Item no. 6

6. Most scientists follow the universal scientific method, step by step, to do their research (i.e., state a hypothesis, design an experiment, collect data, and draw conclusions).					
A. The scientific method ensures valid, clear, logical and accurate results. Thus, most scientists follow the universal method in research.	SD (1) C S 1 0	D (4) C S 4 0	U (4) C S 2 2	A (26) C S 6 20	SA (10) C S 2 8
B. Most scientists use the scientific method because it is a logical procedure.	SD (0) C S 0 0	D (1) C S 1 0	U (4) C S 2 2	A (32) C S 10 22	SA (8) C S 2 6
C. .The scientific method is useful in most instances, but it does not ensure results; therefore, scientists invent new methods.	SD (1) C S 1 0	D (8) C S 2 6	U (15) C S 4 11	A (16) C S 6 10	SA (5) C S 2 3

D. There is no so-called the scientific method. Scientists use any methods to obtain results.	SD (5) C S 1 4	D (12) C S 8 4	U (8) C S 2 6	A (15) C S 2 13	SA (5) C S 2 3
E. There is no fixed scientific method; scientific knowledge could be accidentally discovered.	SD (0) C S 0 0	D (6) C S 6 0	U (3) C S 2 1	A (29) C S 6 23	SA (7) C S 1 6
F. No matter how the results obtained, scientists use the scientific method to verify it.	SD (3) C S 2 1	D (10) C S 4 6	U (9) C S 3 6	A (17) C S 2 15	SA (4) C S 2 2

Item no. 7

7. Is scientific theory (e.g. atomic theory) "discovered" or "invented" by scientists from the natural world?					
A. Discovered, because the idea was there all the time to be uncovered.	SD (3) C S 2 1	D (13) C S 4 9	U (7) C S 3 4	A (20) C S 4 16	SA (2) C S 2 0
B. Discovered, because it is based on experimental facts.	SD (3) C S 3 0	D (8) C S 2 6	U (5) C S 2 3	A (26) C S 6 20	SA (2) C S 1 1
C. Some scientists discover a theory accidentally, but other scientists may invent a theory from their known facts.	SD (2) C S 1 1	D (3) C S 2 1	U (4) C S 2 2	A (28) C S 8 20	SA (6) C S 2 4
D. Invented, because a theory is an interpretation of experimental facts, and experimental facts are discovered by scientists.	SD (2) C S 2 0	D (9) C S 2 7	U (8) C S 5 3	A (18) C S 2 16	SA (5) C S 4 1
E. Invented, because a theory is created or worked out by scientists.	SD (3) C S 1 2	D (8) C S 2 6	U (16) C S 6 10	A (17) C S 4 13	SA (4) C S 2 2
F. Invented, because a theory can be disproved.	SD (1) C S 1 0	D (5) C S 4 1	U (15) C S 6 9	A (15) C S 2 13	SA (9) C S 2 7

Item no. 8

8. Is scientific law (e.g. gravitational law) "discovered" or "invented" by scientists from the natural world?					
A. Discovered, because scientific laws are out there in nature, and scientists just have to find them.	SD (1) C S 1 0	D (6) C S 2 4	U (5) C S 2 3	A (20) C S 6 14	SA (13) C S 4 9
B. Discovered, because scientific laws are based on experimental facts.	SD (1) C S 0 1	D (6) C S 1 4	U (5) C S 2 3	A (29) C S 10 19	SA (4) C S 2 2

C. Some scientists discover a law accidentally, but other scientists may invent a law from their known facts.	SD (1) C S 1 0	D (5) C S 4 1	U (15) C S 2 13	A (18) C S 6 12	SA (6) C S 2 4
D. Invented, because scientists invent scientific laws to interpret discovered experimental facts.	SD (0) C S 0 0	D (17) C S 2 15	U (8) C S 3 5	A (18) C S 10 8	SA (2) C S 0 2
E. Invented, since there are no absolutes in nature, therefore, the law is invented by scientists.	SD (2) C S 0 2	D (24) C S 6 18	U (6) C S 4 2	A (9) C S 2 7	SA (4) C S 3 1

Item no. 9

9. In comparison to laws, theories have less evidence to support them.					
A. Yes, theories are not as definite as laws.	SD (3) C S 2 1	D (9) C S 4	U (10) C S 6	A (20) C S 2	SA (3) C S 1
B. Yes, if a theory stands up to many tests it will eventually become a law; therefore a law has more supporting evidence.	SD (2) C S 2 0	D (3) C S 2 1	U (3) C S 2 1	A (24) C S 4 20	SA (13) C S 5 8
C. Not quite, some theories have more supporting evidence than some laws.	SD (0) C S 0 0	D (11) C S 4 7	U (11) C S 6 5	A (19) C S 2 17	SA (4) C S 3 1
D. No, theories and laws are different types of ideas. They cannot be compared	SD (4) C S 0 4	D (15) C S 6 9	U (14) C S 6 8	A (5) C S 2 3	SA (4) C S 1 3