CHAPTER-7
TOWARDS A TENTATIVE FRAMEWORK FOR PROGRESSION OF SCIENTIFIC CONCEPTION IN CHILDREN…

7.1. Introduction
7.2. Major Findings in Progression Patterns
    7.2.1. Food and Nutrition
    7.2.2. Energy
    7.2.3. Matter
7.3. Towards Development of a Tentative Framework for Progression of Scientific Conceptions
7.4. Conclusion
TOWARDS A TENTATIVE FRAMEWORK FOR PROGRESSION OF SCIENTIFIC CONCEPTION IN CHILDREN...

7.1. Introduction

The primary aim of science education research is improving curricular practice. Science education is an inter-disciplinary study and must derive from disciplines like history of science, philosophy of science, psychology, pedagogy; linguistics to improve curricular practices. The research tradition in science curriculum bifurcates into those research studies focusing on the particular domain of science teaching practices and their emphasis on content in designing teaching and learning sequences; the second set of research studies attends to the needs, learning processes etc. The empirical research and curriculum development are often not integrated. There is a necessity of research on teaching and learning to rethink science content and to reconstruct it from educational perspectives (Fensham, 2001).

Finding from research about children’s learning and development used to map progressions in science at elementary level can be a step forward in this direction.

Although content has been recognised as central component for improvement in curriculum, very little attention is given to the development of increasing sophistication in critical content knowledge, decision needs to be made as to what is critical, and finally what should students know in order to progress to the next level of learning.

In the curriculum design and instruction, a major task is to address the key concepts and generalizations (essentially understanding) related to the critical content of science as discipline. A coherent curriculum is that which fosters through the grades in the deliberate and systematic design, increasing sophistication in critical content knowledge, conceptual understanding and complex performance abilities. Correlating critical content topics at each grade
level with key concepts to be developed shows the conceptual structure of science. The content standards must be articulated over time as a sequence of topics and performances that reflect a logical, sequential or hierarchical nature of the disciplinary content from which the subject matter of science derives. Learning progressions can serve the basis of a dialogue between researchers, assessment developers, policy makers and curriculum developers.

In the previous sections of this study, an attempt has been made to trace the evolution of important concepts of science: ‘Food and nutrition’, ‘Energy’ and ‘Matter’ which have implication for curriculum development at the elementary level.

**7.2. Major Findings in Progression Patterns**

**7.2.1. Food and Nutrition**

The outlines of the food and nutrition concepts were divided into 2 strands such as (i) food and nutrients and (ii) digestion-system and process from the concept map derived from intended curriculum at Indian and international sources.

General analysis of the primary data indicates from the mean that students of Stage3 performed better on the test on the food and nutrition concept compared to the rest of the Stages. Older students understood better, i.e. stage3 performed better than stage2 and stage2 performed better than stage1, though difference between Stage 1 and Stage2 was not statistically significant. The data indicate that as students progress through the science curriculum from primary to middle level, there is a progression in their knowledge about food and nutrition. A bigger sample with a full range of questions on food and nutrition may help to make more definitive conclusions.

Conceptualisation about food and nutrition of elementary students in this study is as follows: *(key: green: scientific conception; red: alternative conception)*

- Food and non-food - Around 90% do not recognise non-familiar food items given in the textbook as food viz-flowers, insects
- **Water as food** - 60% of stage 1 and 77% of stage 2 students consider water as food
- **Glucose as food** - 60% of stage 1 and 73% of stage 3 students conceptualise glucose as food
- **Role of food in the body** - Students of stage 1 are equally divided between (about 33 to 36%) whether people would get ill, become fat or thin because of eating only rice for a month
- **Role of nutrients in the body** - 28% and 47.5% students of stage 1 and stage 2 respectively identify pulses and eggs as body building food
- **Minerals in food** - 28% of stage 1 and 41% of stage 2 students identify Calcium and Iron as minerals
- **Nutrients in food** - 44% of stage 2 students identify proteins in chana
- **Nutrients in ghee** - 20% of stage 2 students think ghee has all nutrients
- **Element present in bones** - 61% of students of stage 1 identify Calcium as the element in bones, which is not part of textbooks but part of exposure to mass media
- **Components in balanced diet** - 36% of students of stage 2 recognise that proteins are the important component which are missing in a given situation, 45% identify fibres wrongly
- **Food made up of cells** - 93% of class 8th students identify easily
- **Micro-nutrients** - 51% of stage 3 students conceptualise that we need micronutrients in milligrams
- **Digestion starts in the mouth** - 54% of stage 1 students conceptualise
- **Chemical Breakdown of food** - 52% of stage 2 and 80% of stage 3 students understand that digestive juices are responsible for breakdown of food.
- **Digestion is complete in intestines** - 10.5% of stage 1, 20.3% of stage 2 and 59% of stage 3 conceptualise that breakdown of food is complete in intestines. However around 50% of stage 1 and 2 conceptualise that it is completed in anus
• **Function of stomach** - 61% of stage1 and 76% of stage3 conceptualise the function of stomach as digestion though around 20% of students think stomach stores food

• **Meaning of digestion** - 54% of stage 3 conceptualise the break down and absorption of food, 22% conceptualise the mechanical passage only

• **Sequence of process of digestion** - 65% of stage3 students conceptualise

Students of both classes within **Stage 1** (9 to 10 years) conceptualised about nutrients in food and digestion in a similar way. Students of class 5th had their exposure to the topic on digestion in curriculum, but it seemed to have marginal effect on them. However, they understand the role of mouth and stomach better than class 4th students. This finding is similar to that of Teixeira (2000) that by the age of 10, the function of the digestive system is explained in terms of functions of organs. The age differences suggest that children’s theory is built on the application of empirical knowledge. The results indicated that the acquisition of the concept of digestion leads to a conceptual revision and enrichment by the age ten.

Similarly if the conceptualisations of students of **Stage 2** (11 and 12 years) are considered, their conceptualisation about digestion, role of various organs or sequence is better than the students of stage1. They could not identify nutrients in food items which shows their lack of content knowledge about nutrients and hence balanced diet also. Most students do not identify what nutrients common food items have and what is missing in a balanced diet. They identify fats and carbohydrates easily. They know the importance of vitamins, minerals and proteins, but cannot identify in food items. They understand the process of digestion better than younger students, but most still have to conceptualise the absorption of digested substances from intestines. The physical process of transformation of food during digestion is understood. Chemical transformation process takes place with the help of glands is conceptualised by many, but the absorption and assimilation is not understood by most students.
The students of Stage 3 (13+ years) have conceptualised most concepts related to food and nutrition inquired of them. They did not find most concepts difficult except one concept on the relation between food and growth. Conceptualisation of it will require understanding of particulate nature of matter and conservation of matter. However, around 28% of students intuitively understood the relation between food and growth which shows that students at this age are probably cognitively ready for abstract concepts like particulate nature of matter.

**Drawing a Historical Parallel between Early Scientists’ and Students’ Conceptions**

- Early understanding of the scientist community was that food has contribution to health without knowing the details; children too understand the various roles of food not knowing the processes.
- Historically, the constitution of food like carbohydrates; proteins being made of Carbon, Hydrogen, Nitrogen etc. were discovered first and later the role and composition of enzymes and vitamins were known. Students understand about carbohydrates and proteins earlier than vitamins and minerals.
- Structures of organs of the digestive system were understood first and later their functions were discovered. Students have knowledge about organs earlier compared to their functions.
- A lot of speculations were made about the function of organs of the digestive system and the process of digestion before it was known finally. Elementary students too have initial ideas about organs like stomach, intestines before progressing to the scientific ideas.
- Around 23.4% of stage 1 and 20% of stage 3 students thought that stomach had a filtering role. Their responses are very similar to the conceptions of medieval physiologists like Galen who wrote that stomach performed a filtering or storing role. Though there was progression in scientific conception about stomach’s role in digestion from stage 1 to 3, the above
said alternate conception persisted and the alternate concept of filtering role decreased considerably.

- From the timeline of food and nutrition, it is understood that evolution of food and of nutrition occurred independently. Evolution in food and digestion stemmed from speculation: speculation about effects of food with health, speculation about role of different organs or glands in the body. Interpretation of observations of experimentations leads to generalisations such as those of Dr. Beaumont. From the study of the evolution of food and nutrition, the implications for school science is that alternate conceptions of students are important starting points for subsequent scientific understandings. Students may comprehend generalisations about food and nutrition from explanation of experiments and subsequent theory-building. Learners would probably understand and describe concepts related to food first, and then understand nutrients of food. Explaining or emphasising the need of including a component or nutrient into diet may not useful for learners till they comprehend the biochemical nature of its transformation inside the body. Hence the attention of students also needs to be drawn to conceptual explanation behind chemical transformation of food, absorption and assimilation.

Drawing a Parallel between Research so far and Students’ Conceptions

- Most students of stage1 had difficulty understanding that insects and flowers can be food of either humans or animals. Though the topic is part of primary text books in Class 3rd, many did not think that people might be eating flowers or insects. They had human centric view point, did not consider animal nutrition at all. This is similar to the findings of Lee, Y.J. and Diong C H, (1999) with secondary students’ (age 16-18 years).

- Around 60% of stage1 students thought water to be food. Above 70% students of stage2 consider water to be food because water is necessary for plants and animals. Text books present water as a component of food while some nutrition specialists consider that organic substances only can be food. Lee, Y.J. and Diong C H, (1999) too have reported in their study that
many students confused the concept of nutrients and water, believing water to be food. Research on Nutrition by Project 2061 (American Association for Advancement of Science, AAAS, 1993) report that lower elementary school children may believe that food and water have equivalent nutritional consequences.

- While 56% stage 1 think that glucose is food in the classification task, 68% of stage 3 students think that glucose is food. The context given for stage 3 students is glucose administered intravenously to a patient. For around 15% of older students, glucose is not food and 12% remain unsure whether glucose is food or not. These 27% students may be considering anything taken orally to be food and not intravenously as was reviewed in CLIS summary, 1992.

- The common alternate conception about ghee in 20% of our students (stage 2) was that fats have all nutrients, suggesting that it is healthy to eat ghee according to them. It is social construction of knowledge for these 20% (72 in numbers out of 360). It is contrary to the understanding of European students (Brinkman & Tuner, 1987 and Dixey et al, 2001) who thought fat was not necessary or rather harmful for them.

- Students of stage 1 were asked about where the digestion process starts. In Yilmaz Cakici’s, (2005) study of Turkish children’s (of the same age) understanding of digestion, only 20.4% children of class 4th and 34.9% of class 5th answered correctly that digestion starts in mouth. In the present study, higher number (54%) of students of the same age has the scientific concept.

- Around 65% of stage 3 identify the sequence of process of digestion correctly, 35% pick incorrect sequence thinking absorption or digestion takes place earlier than ingestion or eating. This alternate conception is similar to the finding of Simpson (1984) who found that at thirteen, children’s ideas of the sequences of digestion are very confused, both in terms of the anatomical route and the processes.

- Around 67% of stage 3 students think that on fasting for 2-3 days there will be fewer nutrients in the blood and seem to understand the relation
between food and nutrients, 11% do not understand it and 18% do not foresee any storage mechanism for nutrients in the body. Francisco Nunez and Enrique Banet, (1997) found that only 69% of students of ages 16-17(who had studied biology) understood the relation between cellular respiration and digestion and that digestion converts complex nutrients into simple substances.

- Only 28% of stage 3 think that particles from food are rearranged in body, 38% think that food accumulates inside the body and 24% think that vitamins and minerals are added to the body unchanged. This finding is similar to the finding by Smith and Anderson, 1985 and Leach et al 1992 under CLIS project. They found that some students of all ages think food is a requirement for growth, rather than a source of matter for growth. They have little knowledge about food being transformed and made part of a growing organism’s body.

The researcher has attempted to articulate the results of this study by different perspectives on progression from the above understanding.

**There has been a progression from phenomenal to conceptual understanding**

- Stage 3 conceptualises glucose as food while stage1 comprehend seeds and meat as food.
- Stage 3 comprehends about glucose as food better scientifically.

**There has been a progression from macroscopic to microscopic understanding**

- Understanding of body structures growing from rearrangement of particles (28% of) by stage 3 students while stage1 students understand that food helps in growth.
- There is a progression in conceptual understanding about chemical transformation of food by digestive juices from stage 2 to stage 3.
There has been a progression in content knowledge

- Stage 3 recalled better about the role of stomach from stage 1.
- Stage 3 knew scientifically about the completion of digestion in small intestines compared to stage 2 and stage 1; stage 2 recalled scientifically more compared to stage 1.

7.2.2. Energy

The outlines of the energy concepts were divided into 6 sub-concepts such as understanding of fuels, renewable and non-renewable sources of energy, sources of energy and pollution/environmental consequences and energy in living systems, meaning of energy and energy transformations under two strands: (i) sources of energy and (ii) energy: meaning, forms and transformations.

General analysis of the primary data indicates from the mean that students of stage 2 performed better on the test on energy concept compared to the rest of the stages. The overall impression showed that there is trend with a dip at the end of the progressive line. Stage 3 and stage 2 have similar understanding of the energy concepts asked and stage 2 and 3 have better understanding than stage 1. The pilot study had not accounted for such trend which appeared in the main study. A bigger sample with a full range of questions on energy may help to make more definitive conclusions.

Conceptualization about energy of elementary students in a nutshell is as follows:

- **Fuels** - 68% of both stage 1 and stage 3 students
- **Identifying Renewable source** - 57.5% of stage 1 students
- **Picking wind as different source of energy** - 74% Stage 1 students 90% Stage 3 students
- **CNG as cleaner source of energy** - 59% of stage 1, 61% of stage 3
- **Problems associated with burning of coal** - 54.2% of Stage 2 students
• Energy source producing no CO\textsubscript{2} is understood by only 17\% of Stage 3 students
• Energy in living system is provided by food is understood by 75\% Stage 1 and 70\%. Energy in living systems is provided by water -19\% approx. By both stage 1 and stage 2 students Stage 2
• In stage 2 students are attempting to conceptually explain energy source of predators other than their food (i.e. herbivore). They have began to conceptualize the need and dependence of predators (secondary consumers) on sun and grass apart from their food i.e. primary consumers (deer in the response)
• Students of stage 1 (47\%) have the concept that your energy levels increase when you exercise well. They themselves feel tired after physical work, they relate building up of stamina (or strength over a period of time) with increasing energy level. Students of stage 1 (34.5\%) think that when you exercise well your energy level decrease
• Form of energy produced in human body is chemical energy (37\%) and form of energy produced in human body is pressure (33\%) - Stage 2 Students
• Form of energy produced in human body is heat energy (63\%) and form of energy produced in human body is force (21\%) by Stage 3 students
• Solar energy stored in wood, grains and sugar is called biomass -51.5\% and Solar energy stored in wood, grains and sugar is called natural gas 30\% - Stage 3
• Energy which is not derived from sun is nuclear energy 21.4\% and energy which not derived from sun is wind energy 41\% - Stage 3
• Electricity is a form of energy (42\%) - Stage 1
• Light energy is a form of energy that is captured by plants to prepare food (52\%) Stage 2
• Sound is a form of energy 71\% Stage 3
• Moving objects have energy (56\%) Stage 1
Moving objects have kinetic energy 45.4% and moving objects have solar energy (26%) Stage 2
Energy is the ability to work (40 %.) Stage 1 and 2, and energy is the power of force 31% - Stage 1, and 41% Stage 2
The transformation of energy in a flashlight is chemical to electrical and to light (42%) and electrical to light and to heat (31%) Stage 2
The transformation of energy in a flashlight is chemical to electrical and to light (19%) and electrical to light and to heat (53%) Stage 3

Students of Stage 1 (9 to 10 years) could conceptualise about sources of energy better than about forms of energy or meaning of energy etc. Students of class 5th identify forms of energy better than class 4 students.

Sources of energy is conceptualised easily by students of Stage 2 (11 years to 12 years). Their conceptualisation about sources and forms of energy is better than the students of stage 1. Transformation of energy from one form to another is not understood by most of the stage 2 students. Most students of this stage had conceptualised about sources of energy and thermal (heat) energy well.

The students of Stage 3 (13+) have conceptualised most concepts related to energy inquired of them. They had difficulty in conceptualising transformation of energy in a flashlight, and nuclear energy. Conceptualisation of it will require understanding of forms of energy in various contexts and the transformation of energy from one form to another. However, around 19% of students intuitively understood the concept of transformation. They could have used their conceptual understanding about conventional sources and answer about nuclear energy. Concepts on forms of energy and sources of energy were easily understood by most of the class eighth students. From the primary data, one may generalise that students of stage 3 i.e. older students understand concepts of sources of energy better than junior students, but students’ understanding of energy concepts did not improve in class 8th despite their exposure to energy-related concepts like heat and temperature, combustion, electricity, fuels etc. Students may require direct instruction in the topic energy rather than covertly placed energy topics.
Drawing a Historical Parallel between Early Scientists’ and Students’ Conceptions on Energy

- The term energy meant activity and had been used with this meaning in the 18th century and in the first part of the 19th century. In 1851, William Thomson, later on Lord Kelvin, used the word to refer to the mechanical activity of a body, i.e., its capacity of doing work. Students too relate to energy through activity easily. The division into two sets – static and dynamical – of the stores of activity available led to the distinction between potential and kinetic energy. From the timeline of energy, individual scientists had understood and coined kinetic energy in the year 1829 and potential energy in 1853. Around 56% of stage-1 understands that moving objects have energy (kinetic energy). Though a high percentage 20-26% also thought that there is no energy in the moving objects they could relate to movement and energy conceptually, without instruction in this area. Kinetic energy is related to energy in moving objects and is easily observed compared to potential energy. Historically too kinetic energy was discovered earlier than potential energy.

- A question was put to students of stage-1 and stage-2 to identify the definition of energy. About 31.5% of stage 1 and 41% of stage 2 equates energy with force. This alternate conception has been earlier found by Watts and Gilbert (1986) that students use energy synonymously with force or power.

- Many researchers (Viennot, 1979; Watts & Gilbert, 1983; Duit, 1984) have noted that students fail to differentiate between energy and other physical terms, mainly the concept of force. This reflects the confusion between energy and force which scientists had during historical evolution of energy.

Drawing a Parallel between Research so far and Students’ Conceptions

- The concept related to sources of energy are related to the context of students’ experience and easily understood compared to the forms of energy or transfer of energy which requires understanding the energy model conceptually. The science instruction does not prepare most of the students...
to see beyond phenomena and understand the conceptual explanation of the phenomena. This is corroborated by Papadouris’ et-al (2008) study.

- About 75% of stage 1 and 70% of Stage 2 identifies food as source of energy for man. Around 19% students of both stages have alternate concept that water is a source of energy. These findings can be compared to those of Boylan C (2008) with elementary students (mainly class 3rd to 6th) of Australia where 34% elementary students had the understanding that eating food gives us energy, and 38% of them thought sleeping gives us energy and 28% thought that the energy in our bodies comes from drinking water. So relatively less students (19% compared to 28%) in our context have the alternative concept and more students (70 to 75% compared to 34%) have scientific concept.

This also relates to the previous section on Food and Nutrition where in the classification task, a majority consider water to be food because water is necessary for plants and animals.

- Upper primary students have not been formally introduced to forms of energy, but 38% approx. of stage-2 and 63% of stage-3 understand the forms of energy produced in human body scientifically. Learners typically start with the ideas of energy related to personal experiences of human activities (Solomon, 1982).

- About 21% of stage-3 students confused force with energy. Young students as well as adults like the pre-service teachers have been known to have this intuitive view about energy (Trumper, 1995).

- To the questions whether our energy levels are increased or decreased after exercise, 34.5% of stage 1 students think that energy will be depleted, but higher percentage of 47% think alternatively that energy is increased after exercise. They themselves feel tired after physical work, but here they relate to building up of stamina (or strength over a period of time) with the increasing energy level. A recent study by Mann and Treagust (2010) with students of 8-12 years in Australia through an open-ended questionnaire also have pointed out that there is limited understanding of energy use, energy conversions and energy transfers in the body. Understanding about
role of respiration in conversion of food into useable energy increases from age 8 to age 12 in a progressive way. ‘Building up of energy’ is one such idiom used in common parlance which was the source of alternative idea.

- About 62% of Stage 2 students responded scientifically that light energy is utilised during photosynthesis, a large number of students (32%) think that heat energy of sun is utilised during photosynthesis. This finding is corresponding to the findings of Hirca N, Calik M and Akdeniz F (2008) in which about 60% of grade 8 students (from 9 schools of Turkey) had this scientific understanding.

- About 31.5% of stage 1 and 41% students of stage 2 have alternate conception and equate energy with force. This has been earlier found by Watts and Gilbert (1986) that students use energy synonymously with force or power.

- More than 20% of the students also have an alternate concept that energy is something you need to live. Anthropocentric viewpoint about energy was listed among many frameworks that students have by Watts, (1983). Many researchers (Viennot, 1979; Watts & Gilbert, 1983; Duit, 1984) have noted that students fail to differentiate between energy and other physical terms, mainly the concept of force.

The researcher has attempted to articulate the results of this study by different perspectives on progression in energy concepts from the above understanding.

*There has been progression from phenomenal to conceptual understanding in energy concepts*

- While stage 1 understood about sources of energy and fuels used, stage 3 had conceptual understanding of the meaning of fuels.

- Progression may also be inferred when students of stage 3 conceptualised the processes by which fossil fuels are formed and younger students are able to identify fossil fuels from other fuels.

- Stage 3 students were able to conceptualise environmental consequences of using different fuels and compare them in terms of CO₂ emission.
Students of stage 3 and 2 were able to apply their understanding about forms of energy in human body while students of stage 1 understood about some forms of energy.

Progression within the stage may be inferred to a small extent when students of stage 2 had to identify that a source of energy heats a solar cooker and a gas stove as a common explanation. Around 38% of class 6th and 51% of class 7th understood the common explanation of source of energy correctly (44.4% of stage 2 students). About 24.6% thinks that gas heats a solar cooker as well as gas stove.

**There has been a progression in the content knowledge**

- Stage 3 knew more about sources of energy compared to other stages.
- Stage 3 knew about renewable sources of energy with certainty over stage 1.
- Stage 3 identified forms of energy better than stage 2 and stage 1.

### 7.2.3. Matter

The outlines of the energy concepts were divided into 5 strands such as understanding of (a) Properties of materials (b) Physical processes such as freezing, boiling, evaporation and condensation (c) Conservation of matter (d) Chemical properties and (e) States of matter.

An observation of the mean shows that students of Stage 3 performed better on the test on the matter concept compared to the rest of the Stages. Stage 2 performed better than stage 1. Statistical differences between all stages were inferred. The data indicate that as students progress through the science curriculum from primary to middle level, there is a progression in their knowledge about matter concepts. Cognitive maturity of stage 3 appears to shift their understanding about matter towards progression. A bigger sample with a full range of questions on matter concepts may help to make more definitive conclusions.

Conceptualisation about materials of elementary students in a nutshell is as follows:
• Conservation of mass in shape transformation-- 50% Stage 1
• Conservation of mass in freezing( weight in grams)-18% Stage 2
• During freezing, the mass( weight in grams) increases-45.5% Stage 2
• The change of state from water to water vapours during boiling was one of the better understood concepts by elementary students
• Around 53% students understood that steam consists of water vapour
• Evaporation at normal temperature was not so well understood
• Around 36% average of Stage 1 conceptualized that clouds had water droplets
• Clouds are made up of sea water-47% Stage 1
• Condensation was not understood by most Stage 2 and 3 students
• Water on cold bottle comes from H₂ and O₂ of air-50% of Stage 2 and 3.
• Conservation of mass in dissolving- 48% of Stage 2
• Mass(in grams) decreases from combined mass of sugar and water-29%
• Digestion as chemical change-only 41% of Stage 3
• Melting of Butter as physical change-44% of Stage 2
• Weight change in chemical change is understood by less than 30% of Stage 3
• chemical change produces a new substance-47% of Stage 3
• Chemical change always occurs between liquids-22% of Stage 3
• Chemical reaction occurs between solids, liquids and gases-71% of Stage 3
• 45% of students of Stage 1 and Stage 2 ascribed gas to be a non material
• Around 20% students across Stage 1 and 2 considered milk (a liquid) not to be material, so overall 60% to 70% of elementary students up to Stage 2 had not conceptualized material and non material.

From this study of students’ conception about materials from age 9 to 13 and above it was found that students of Stage 1 find 7 concepts out of 13 concepts, difficult .Three of these concepts are related to change of state, one each is related to characteristics of air and properties of material, and two are related to identifying features of solids, liquids and gases. The concepts related to their experience and perception like conservation of mass and freezing, evaporation being faster outside etc was found easy by them.
The students of **Stage 2** found 5 concepts difficult. Students of this stage found conservation of mass during freezing, chemical change, condensation, and states of matter concepts difficult. Identification of chemical change is conceptualised easily by 7th better than 6th.

The students of **Stage 3** conceptualised most concepts related to material inquired of them.

**Drawing a Historical Parallel between Early Scientists’ and Students’ Conceptions**

Maximum students at 45-46% of stage 1 and 2 think that CNG is not material. Gases were not considered as material till the 17th century when air was known to have weight and was known to be made up of particles.

From the timeline of matter, it is evident that individual scientists were speculating about the structure of matter for a long time before Dalton brilliantly summed up the previous discoveries to come up with atomic theory in 1800CE. The material properties of gases were discovered before that. Elements were known earlier than the atomic structure. Model building by scientists helped to develop particulate nature of atoms from the discovery of various sub-atomic particles.

From the study of the evolution of matter, the implications for school science is that it is difficult to understand particulate nature of matter. They would probably understand and describe phenomena related to matter like evaporation and condensation first, and then explain them scientifically with the particulate nature of matter. Conceptualizing particulate nature of matter would be possible once students are ready to build mental models of matter. The attention of students also needs to be drawn to conceptual explanation behind physical phenomena like evaporation, condensation etc. for a progression.

**Drawing a Parallel between Research so far and Students’ Conceptions**

- More than 40% to 50% of students of Stage 1 and 2 ascribed gas to be a non material (there was no change in understanding gas as a material across stages). Studies (Johnson and Driver, 1991; Piaget, 1929, Sere, 1985, Stavy, 1988) also report students of all ages having vague perceptions of the gas state and not considering gases as substances.
Only 40% of Stage 2 students consider fire as non-material which is the scientific concept. This is similar to the findings Stavy, (1991) and Lee et al, (1993) that elementary students may consider anything that exists as matter including heat and electricity.

Students of Stage 1 were asked where the water from wet clothes goes upon drying. As many as 16% just described the event saying water just disappeared. Around 39% students understood that water had gone into the air. Little more than 25% of the group thinks that water breaks into H$_2$ and O$_2$gas; this answer is popular because it sounds more scientific. All these conceptions of children about evaporation have been reported earlier by Bar, (1989); Osborne & Cosgrove, (1983).

Bar and Travis (1991) found that 70% of a sample of 6 to 8 year olds understood that vapour is made of water. In the present study less number of students with only 58% of 9 to 10 age could conceptualise that steam is made of water vapours, majority students thought water breaks into H$_2$ and O$_2$.

The conception about condensation of Stage 2 and 3 with the findings of previous researchers can be compared by the following table.

<table>
<thead>
<tr>
<th>Concept</th>
<th>Researcher</th>
<th>Age</th>
<th>Scientific Concept</th>
<th>Alternative Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condensation - water on cold</td>
<td>Present Study</td>
<td>11-12</td>
<td>Air-13%</td>
<td>H$_2$ and O$_2$-49%</td>
</tr>
<tr>
<td>bottle comes from?</td>
<td></td>
<td>13+</td>
<td>25.5%</td>
<td>55.5%</td>
</tr>
<tr>
<td>Osborne and Cosgrove, 1983</td>
<td>12-15</td>
<td>10%</td>
<td>60%</td>
<td>-</td>
</tr>
<tr>
<td>Bar and Travis, 1991</td>
<td>10-14</td>
<td>20%</td>
<td>40%</td>
<td>40%</td>
</tr>
</tbody>
</table>

In the present study, higher percentage (at 48%) of students of age 11 and 12 compared to Driver’s sample of 15 year olds in 1982 where 33% had scientific idea that mass of solution will be the same as constituents while dissolving.

There has been progression from phenomenal to conceptual understanding in matter concepts

- Conceptualization of non material improved from stage 1 to stage 2. More students of stage 2 could understand that fire is not material compared to students of stage 1.
• Conceptualisation about volume and hence characteristics of the three states of matter: solids, liquids and gases enhances to a marked extent from stage 1 to stage 3.
• Conceptualisation about solid or non-solid improved within the stage 1 ie from class 4th to 5th.

**There has been a progression from macroscopic to microscopic understanding**

• Physical change conceptualization- increases from Class 6th to 7th (36%-51%)
• Chemical change- conceptualization improves across classes from stage 2 to stage 3
• Identification of features of liquids and gases- improves to a large extent in stage 3 from stage 1 (18% to 76%).

**There has been a progression in content knowledge**

• The properties of metals were better understood by stage 3 students compared to Stage 2.

7.3. Towards Development of a Tentative Framework for Progression of Scientific Conceptions

The progression patterns interpreted from the field indicate that there are some strong alternative concepts and other alternative concepts, the sources of which are various and need to be addressed at various levels by stakeholders in the curricular process. However, for a smooth progression from naïve, contextual, personal conceptions to shared scientific conceptions, designing a coherent curriculum is implied.

From the findings of the present study and recent trends in science education research, the researcher has attempted a tentative framework for fostering learning progressions in science.
Fig. 7.1: A Tentative Framework Fostering Learning Progression

Primary data generation

Tasks, activities, of questions to reflect student understanding

Secondary sources

Pedagogical perspectives of the concept

Historical evolution of the scientific topics

Collated concept maps from both sources

Analysis of intended Indian curriculum

Analysis of intended international curriculum

Progression

- Strong alternative concepts to be plugged
- Scientific concepts
- Improvised line of progression (not to scale)
The steps of the framework are:

- For reconstruction of science curriculum, the intended curriculum is the logical starting focus
- Major scientific concepts may be analysed from the intended curriculum.
- The concepts may be analysed for the breadth and coverage in the intended curriculum
- The same concepts may be analysed from international curricula for breadth and coverage for comparability
- Developing concept maps from both national and international sources
- Collating a concept map from both sources keeping in view the conceptual resources present with students of a grade level from the existing curriculum
- Identification of conceptual dimensions or strands within the major concepts
- Designing tasks or questionnaire etc to reflect students’ understanding
- Primary source is derived after data is generated from a large sample and analysed
- The pedagogical perspective derived from review of research carried worldwide becomes a part of secondary source
- The scientific evolution of the concept derived from literature is also analysed
- A tentative framework for fostering a learning progression is developed from both processed primary and secondary data

7.4. Conclusion

Student-related issues such as naïve conceptions, alternative conceptions, and cognitive ability find reflection in the primary source and interpretations from pedagogical perspectives.

Science aspires to build conceptual structures with sound explanatory and predictive power which is neither explicitly nor implicitly mentioned in
elementary curriculum. The role of interpretation or the active role of scientists in knowledge construction process is neglected and knowledge construction is represented as experiments. The collation of scientific evolution will even out this lacunae and will lend to the science education-related issues.

The coherence of the emergent framework is derived from the balance between educational and student-related issues.