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RESEARCH DESIGN

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CHAPTER-3
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3.1. Introduction

Our emergent understanding of the way young students acquire domain-specific knowledge in the sciences can inform the planning and sequencing of science curricula. Development of science concepts may not be a primary goal of science education. But conceptual understanding may be seen as an appropriate goal of curriculum and then instructional courses may benefit from planning which draws on knowledge of the way in which understanding of science concepts evolve. A wide range of factors including social and cultural aims, are taken into account when decisions are made about curriculum content in school science courses. If courses are to be related appropriately to learners, curriculum decisions are to be taken on the basis of processes of knowledge acquisition across age.

A purposeful science curriculum should aim to sustain and develop the curiosity of young people about the natural world around them, and build up their confidence in their ability to inquire into its behaviour. It should seek to foster a sense of wonder, enthusiasm and interest in science so that young people feel confident and competent to engage with scientific and technological matters. Moreover science curriculum should help young people acquire a broad, general understanding of the important ideas and explanatory frameworks of science in addition to the procedures of scientific inquiry (Robin Millar and Jonathan Osborne, 2000).

Evolution refers to the progression patterns among various aspects of major science concepts across elementary classes in the context of this study. Given the complexity and counter-intuitive nature of the desired end point, curriculum sequences should be guided by a long term vision and understanding about what might be truly foundational and most important to teach. Hence the research design calls for an exploratory approach of finding focus of science curricula, science concepts, original researches, assessment tools and finally emerging understanding from field data.
The review of the related research studies on cognitive psychology, conceptual change and science studies has helped the researcher to build an understanding of the research problem. This chapter takes the research further by discussing the design of the study, the sample selected for the study, research tools and methods employed for analysis.

3.2. Approach to the Study

In order to study how learners’ ideas about the identified concepts develop from classes 4th to 8th it is necessary that completed research about conceptual understanding of these and other related topics from all around the world would be reviewed and also to undertake original research.

Producing questions from syllabus/text books would not allow for probing of the underlying concepts used by learners to explain phenomena and how these concepts differ at different ages. The statements in text books/syllabus are end points of learning; demonstrated by learners as a result of having acquired skills, process and concepts. It is not necessary that individual learner’s ideas will develop in the same way. Hence syllabus statements cannot be viewed as a hierarchy through which all children will progress. It is necessary to

- Identify the key scientific ideas to be addressed.
- Conduct conceptual analysis to identify demands of the syllabus/text books of each class from a scientific perspective to select major concepts.
- Identify key scientific ideas which constitute the three major concepts.
- Study the history of discovery of key scientific ideas within the three major concepts.
- Administer these questionnaires to a large sample of elementary students.
- Analyse the children’s responses to document how the prevalence of these ideas changes with age.
The study was undertaken in two phases. The first phase was collection and interpretation of secondary data and the second phase consists of data collection from field and its interpretation.

The first phase of the study was carried out in 5 steps:

- A comprehensive analysis of the content material of elementary science curriculum to locate the major concepts for the study
- An analysis of content sequence of those major concepts from the international science curricula at the elementary level.
- Developing concept maps of identified concepts from both intended and available international curricula
- Development of timeline from history of evolution of those science concepts
- Collating pedagogical perspective of the identified concepts from different research studies.

The following section summarises the first phase of the study, methodology adopted, tools adopted to collect and interpret data.

### 3.3. Data Collection: Secondary Sources

#### 3.3.1. Analysis of Intended Curriculum: Indian Source

The cultural contribution of science can be realised by introducing a set of major ideas about the material world and how it behaves, such as the particle model of matter, the germ theory of diseases, the gene model of inheritance, the heliocentric model of the Solar system etc. in the science curriculum. These ideas fall within the broad themes of living things, matter, the universe, and the made world. In focussing on the detail i.e. by setting out the content as a list of separate items of knowledge, the major ideas of science are lost sight of. Without a change of focus, it is impossible to see whether we are looking at a beautiful building or a pile of bricks. An over-concentration on the detailed content of science may prevent students appreciating some of the most powerful and significant pieces of knowledge. At the end of formal science education pupils may emerge with the feeling that the knowledge they acquired were a pile of bricks and the scientific edifice is for the scientific elite.
Analysis of Elementary Text Books, NCERT

The intended curriculum or the prescribed curriculum is designed by Educational authorities in a country and is intended for the instructional guidance. In our country, NCERT is an apex body under the Ministry of Human Resource Development (MHRD) which is responsible for preparing curriculum guidelines for the entire country. It also develops and publishes text books based on the guidelines prescribed in the National Curriculum Framework. Since education is in the concurrent list, most of the states, develop their own curriculum based on the national curriculum framework. Some of the states adopt the NCERT textbooks translating it in regional languages (e.g. as in case of Delhi State) and other states adopt them to suit their local contexts. With an experience in the field, the researcher has found that private publisher or publishers of the state board mostly develop text books in the same lines as the NCERT textbooks and hence NCERT textbooks were selected as symbolic source of intended curriculum in the Indian context The syllabus guidelines for elementary classes for environmental studies (from class 3rd to class 5th) and science (from class 6th to 8th) were looked into. At the primary level, science is part of environmental studies and not as a separate subject. At the upper primary level science is taught as a compulsory subject. The textbooks from class 3rd to 8th and syllabus guidelines of elementary classes were analysed to derive concept maps. The syllabus guidelines and textbooks are available at www.ncert.nic.in. After Starr and Krajcik (1990), significant content was separated from trivial content to focus the attention on teaching concepts and distinguishing intended curriculum from instructional techniques (Stewart et al, 1979).

The outline of major concepts and sub concepts of science has been drawn in the coming sections. To understand the placement and depth of the concepts in each grade, the researcher identified the ‘conceptual dimensions’ (Savinainen and Scott, 2002; Stevens et al, 2009) / strands under a science concept. Ideas that describe concepts related to or necessary for understanding were collected and categorized within these conceptual dimensions or strands. Because of the nature of the field, many ideas fall into multiple dimensions, but are considered in anyone dimension while analyzing.
Based on these guiding ideas, textbooks of elementary classes of NCERT were analysed.

The curriculum of science post-NCF, 2005 up to Class 10 is organised around themes that are cross-disciplinary in nature. A single set of themes is used, from Class 6 to Class 10. The themes are: Food, Materials, The World of the Living, How Things Work, Moving Things, People and Ideas, Natural Phenomena and Natural Resources. These themes run all through the classes and there is a consolidation of content in higher classes. In the primary classes, the ‘science’ content appears as part of EVS, and the themes are largely based on the children’s immediate surroundings and needs: Food, Water, Shelter etc. In order to maintain some continuity between Classes 5 and 6, these themes are made to naturally continue into the seven themes listed above as per NCF, 2005.

Content Analysis

The researcher has undertaken an in-depth analysis of each chapter of all the text books (class 3-8) to categorise the content into major concepts. The purpose of content analysis was to examine the placement, depth and progression of content across the elementary grades. Food & its Components, Properties of Material/Matter, Plants, Animals, Characteristics of Living Organisms, Conservation, Measurement and Motion, Light, Electricity and Magnetism, Air, Physical Phenomena, Natural Phenomena, Water, Soil are the major concepts along which the Science curriculum at the elementary level could be classified. The major concepts were identified from the perspective of structure of science as a discipline which was not possible within the given themes. At the primary level, the concepts are at the introductory level and learners at this level are expected to be acquainted to the topics through their social experiences and few hands-on-activities. The concepts at a more descriptive level in as much detail as a chapter is presented in bold compared to the concepts at introductory level of presentation (Table 3.1). Concept maps of these 14 major concepts were constructed to trace the depth of content coverage and how the strand emerges across elementary classes. Many concepts such as Force or health concepts had limited presentation across elementary classes and many concepts were dealt only at the phenomenal level (e.g Light) for which primary students would not have the conceptual understanding.
<table>
<thead>
<tr>
<th>Concepts/Topics</th>
<th>3rd</th>
<th>4th</th>
<th>5th</th>
<th>6th</th>
<th>7th</th>
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<tbody>
<tr>
<td>1. Food &amp; Components</td>
<td>Cooking, What we eat, What animals eat</td>
<td>How food reaches us, honey as food</td>
<td>Spoilage &amp; wastage of food, Food preservation, Food habits, Food chain</td>
<td>Food and components</td>
<td>Animal nutrition</td>
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<td>2. Properties of Material/ Matter</td>
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<td>Different materials for construction</td>
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<td>3. Plants</td>
<td>Diversity of plants, Dependence of humans on plants</td>
<td>Trees wild and domestic, Roots and flowers</td>
<td>Seed germination, Plant parts, Seed dispersal, Plants from different countries</td>
<td>Plant and its Parts, Need for fertilizer and irrigation, Different quantities for different crops, Sources of irrigation</td>
<td>Plant nutrition, Plant reproduction</td>
<td>Crop production</td>
</tr>
<tr>
<td>4. Animals</td>
<td>Pets and other animals, Insects, Birds, Animal foods</td>
<td>Group behaviour, External ear, Body hair, Animal shelter, Bird nest, Tongue and teeth, Babies come from mothers</td>
<td>Animal products used by us, Protection of wild life, Chest expansion and contraction and breathing, Digestion in the mouth</td>
<td>Joints and Movements</td>
<td>Animal nutrition, Respiration</td>
<td>Reproduction in animals, Growth in humans hormones</td>
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<td>5. Characteristics of Living Organisms</td>
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<td>Micro organisms, Animals and plants in water</td>
<td>Characteristics of Living Organisms, Habitat</td>
<td>Adaptation</td>
<td>Cell structure and Function, Micro organisms</td>
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<td>6. Conservation</td>
<td>Effect of deforestation, Forest products, Fuel conservation</td>
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<td>Forest our lifeline</td>
<td>Conservation of plants and animals</td>
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<td>Concepts/Topics</td>
<td>Classes</td>
<td>3rd</td>
<td>4th</td>
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<td>7. Measurement and</td>
<td>Measurement, Motion</td>
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<td>Motion and time</td>
<td>Reflection, Reflection, Force and Pressure</td>
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<td>Motion</td>
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<td>8. Light</td>
<td>Braille System</td>
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<td>Shadows and Reflections</td>
<td>Refraction, Dispersion through prism</td>
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<td>9. Electricity and</td>
<td>Circuit, Insulator and Conductor, Magnet</td>
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<td>Heating affect of the electricity, Fuse,</td>
<td>Chemical effect of the electrical current, Electroplating</td>
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<td>Magnetism</td>
<td>and properties</td>
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<td>Electromagnets</td>
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<td>10. Air</td>
<td>Components of air, Composition of air,</td>
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<td>Air exerts pressure, Air pressure and winds, Air expands on heating</td>
<td>Air pollution, Global warming and green house effect,</td>
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<td>Soluble oxygen, Oxygen cycle</td>
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<td>11. Physical Phenomena</td>
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<td>Heat</td>
<td>Sound, Stars and Solar system</td>
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<td>12. Natural Phenomena</td>
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<td>Weather climate, Storms and cyclones</td>
<td>Lightning, Earthquake</td>
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<td>13. Water</td>
<td>Sources and uses of water, Recycling</td>
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<td>Sources of water, Water cycle,</td>
<td>Water a precious resource, Ground water, Water management, Sewage, Wastewater treatment plant, Sanitation</td>
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<td>conservation of volume</td>
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<td>Evaporation, Transpiration, Water Conservation</td>
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<td>Sources inland and sea, Purification,</td>
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<td></td>
<td>Evaporation and condensation, Water pollution</td>
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<td>14. Soil</td>
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<td>Soil</td>
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</table>

The concepts at a more descriptive level as a chapter are presented in bold compared to the concepts at introductory level.
3.3.2. Analysis of Intended Curriculum: International Source

Elementary science curricula of USA (AAAS, project 2061), Australia (Australian Curriculum and P-10 continuum: achievement standards of State Victoria) and National Curriculum, U.K were analysed to find the content strands present in them. The key scientific concepts identified in this study relate closely to the science syllabus of elementary classes as prescribed by NCERT but the treatment is different.

In U.K., National Curriculum is adopted since 2007 though it has been placed for review since Jan 2011. At the primary level, science is a compulsory programme of study with attainment level target descriptions delineated for key stage 1 (5-7 year old) and key stage 2 (7-11 year old). The science at key stage 1, key stage 2 consists of Life Processes and Living things, Materials and their properties, Physical Processes including scientific enquiry to be initiated through contexts from the earlier mentioned 3 content areas. Breadth of study refers to knowledge, skills and understanding to be developed in students of grades 1 to 6. At key stage 2, pupils are taught life processes, nutrition, circulation, movement of humans and other animals, green plants & their nutrition, adaptation, food chain and micro organisms under life processes. Students are given the knowledge, skill and understanding of grouping and classifying materials including solids, liquids and gases, chemical and physical change and separating mixtures under the theme materials and their properties. Under physical processes students are taught about simple circuits, forces and motion, light and sound, sun, earth and moon. The content of science at key stage 3 (12-13 years) includes energy, electricity and forces, chemical and material behavior including elements, compounds and the particle model, life processes, behavior and health.

Australia has recently moved from state based to national curriculum. The Australian Curriculum was adopted in Dec 2008 by the council of state & territories education ministers. As of 2012, the Australian National Curriculum has been adopted by some schools and will be mandatory soon. Several
agencies at the level of states & territories and international agencies provide education through schools in Australian states. All schools government, Catholic or independent schools are required to adhere to the same curriculum frameworks of their state or territory.

Science in the Australian Curriculum (2008) has three inter-related strands: Science understanding, Science as a human endeavor and Science inquiry skills. These strands operate through the sub-strands of biological sciences, chemical sciences, physical sciences and earth and space sciences. The curriculum focus for years 3-6 (students from 8 to 12 years of age) include the content areas of movement of earth materials, heat, living things, forces, light, (structure of matter) solids, liquids, gases and their properties, chemical and physical changes electric circuits and energy sources to generate electricity. Year 7 content includes classification and diversity of organisms, food chains and food webs, mixtures and separation of substances, water-an important resource, renewable & non renewable resources, force and motion, gravitation By the end of year 8 pupils are expected to have knowledge and understanding of particle model to explain the properties and behaviours of substances, forms of energy and transformations, cells and body systems.

National Science Education Standards, (1993, 2009) U.S. describe the subject matter of science using 3 divisions of science: physical science life science and earth and space science standards. The physical science standards for level K-4 include properties of objects and materials, position and motion of objects light heat, electricity and magnetism and those for Levels 5-8 includes properties and changes of properties in matter, motion and forces and transfer of energy. The life science standards for level K-4 (grades 1 to 4) include characteristics of organisms, life cycles, organisms and their environment and standards for levels 5-8 (grades 5 to 8) include structure and function in living system reproduction and heredity, populations and diversity, adaptations of organisms. The earth and space science standards for level K-4, properties of earth materials, objects in sky and level for levels 5-8 include mostly solar system concepts.
Three major concepts identified from analysis of elementary science curriculum of NCERT and other countries were Food and Nutrition, Energy and Energy Sources, and Materials/ Matter. To converge on important science concepts in elementary science curriculum is not an easy task. Important science concepts were identified after review of related literature, analysis of international science curricula and analysis of syllabus as well as text books for elementary classes of E.V.S. and science.

3.3.3. Development of Concept Maps

Concept maps were developed to fulfil the following objectives:

- To understand what the intended curriculum includes in the area of food and nutrition, energy and matter in Indian context
- To identify what constitutes ‘standard’/expected knowledge in these topics from available curricular resources.
- To derive a concept map from the maps mentioned above to form a basis for developing questionnaire

Concept maps can be defined as visual representations that are added to instructional material to communicate the logical structure of the instructional material. The concept map serves as a device to illustrate the hierarchical conceptual and propositional nature of knowledge. The concepts are arranged in a hierarchy with a superordinate concept at the top. The concepts are linked by lines labelled with connecting words that form the proposition unifying the concepts. Concept mapping requires the mapper to prioritise and make judicious use of selected concepts when mapping. It involves identification concepts in study materials and their organisation from the most to least general, more specific concepts.

Concept maps are flexible tools that can be used in a variety of educational settings (Stewart, Van-Kirk and Rowell, 1979). They have been used as a tool for assessing meaningful learning (Novak, 1979) as well as in curriculum planning,
instruction and evaluation (Stewart et al, 1979). Concept maps are useful in science curriculum planning for separating significant from trivial content (Starr and Krajcik, 1990) and focussing the attention of curriculum designers on teaching concepts and distinguishing intended curriculum from instructional techniques (Stewart et al, 1979). Science education reforms have developed concept maps to decide which concepts are the most important to learn and use, what are important concepts that contribute the big picture or pervasive principles at the core of scientific disciplines. Science educators extract, select and prioritize concepts from information-dense materials (Jonassen, Biessner and Yacci, 1993).

AAAS Project 2061 (The American Association for the Advancement of Science) and the National Science Teachers Association published two volumes of Atlas of Science Literacy in 1993. The two volumes include nearly 100 maps which chart all the learning goals specified in Bench marks essential for every student to learn. The maps given in the Atlas of Scientific Literacy illustrates the relationships between individual learning goals and shows the growth of understanding of ideas. Connecting arrows indicate the connections between ideas which are based on the logic of the subject matter (or on cognitive research about how students learn). The maps are available at http://www.project2061.org//tools//benchol/bolframe.html

The Department of Education and Early Childhood Development (DEECD), State Government of Victoria, Australia has developed the science continuum P-10 for effective science teaching. The Science Continuum P-10 identifies focus ideas at each level of essential learning standards for science. Connections between concepts and pathways of student’s concept development maps are mapped in science concept development maps. The concept developmental pathways are the ones students may take when developing scientific understandings. They demonstrate the relationship between concepts, how concepts contribute to a range of scientific fields and how concepts of increasing complexity are developed from more simple understandings. The concept maps

The development of concept maps of Food and Nutrition, Energy and Matter was taken up by analysing (a) the Environmental Science Textbooks (class 3rd to 5th) and Science Textbooks of NCERT (class 6th to 8th) and (b) International standards in science and other curricular material available through web resources.

3.3.4. Collating History of Evolution of Science Concepts

Science is seen as the result of human endeavour, involving creativity and imagination as well as the careful collection of data and interpretation of data to generate evidence. Science as a body of empirical, theoretical and practical knowledge about the natural world has a long intellectual and social history. The history of science provides many examples of change in how things, for example, the solar system, are understood. Looking back, knowing the evidence that eventually supported the new ideas, these ideas may seem obvious, but at the time they often required a leap of creative thinking that led to the collection of supporting evidence – a mixture of inductive and deductive reasoning. History of evolution of the selected concepts of food and nutrition, energy and matter has been collated from publications and available web resource to understand the nature of content of these three major concepts.

3.3.5. Collating Pedagogical Perspective of Science Concepts

The pedagogical aspect of content structure of the selected concepts would help the researcher to build a perspective on how elementary students understand the concept, whether there are obstacles in understanding it, and to finalise the conceptual statements based on which questions would be framed. This perspective also would provide a background for analysis of primary data. Pedagogical perspective has been collated from the summaries of reviews and other research conducted by nutritionists, physicists, chemists
and other researchers from the perspective of science education, cognitive psychology or child development.

3.4. Data Collection: Primary Source

The second phase consists of data collection from field and interpretation from both primary and secondary data. This section summarises the steps taken to select the sample, collate and develop tools, data collection and analysis.

3.4.1. Methodology of the Study

The study is cross-sectional in nature, because it is suited to gather a large sample of elementary students’ views across age groups. Longitudinal designs have the potential for documenting intra-individual change, but participant attrition, high cost in time, personnel and money and potential influence of unexpected social events on participants are some of the disadvantages. Limitations of cross-sectional approach are that intra-individual change is inferred rather than being measured actually and age differences may show trends particular to a group and not development change.

These disadvantages are attempted to be evened out with a large sample and purposive sampling approach which has the advantage of being able to generalize the results to other populations.

A cross age methodology was used in this study. Students from class 4th to 8th were selected and their conceptual development about three science concepts was explored using appropriate research tool. Three questionnaires were developed to probe children’s ideas about each of the key scientific ideas, one for classes 4th and 5th, second questionnaire for classes 6th and 7th and the third one for class 8th. Students of class 4th and 5th are of roughly 9-10 years of age. It is assumed that they are in the concrete operational stage of Piaget and similar cognitive maturity. Conceptually too they may be assumed to be at almost the same level since not too many science concepts are introduced at the early elementary classes. Class 4th and 5th was considered as stage1.
Students of classes 6th and 7th are roughly of 11-12 years of age and are in the transition period of Piagetian stage of formal operations and were considered to be stage-2. Students of 8th class are at the end of elementary level and are in the Piagetian stage of formal operations. For the purpose of convenience, 8th class was considered as stage-3 being the terminal stage for elementary level and they have linked all the concepts during the science instruction for 3 years.

3.4.2. Sample

The sample for final administration of the questionnaire is approximately 200 students from each class, across 4th to 8th. A total of 957 elementary students of five schools of Delhi were administered the questionnaire. The sampling was purposive random sampling (hence non-probability) which allowed the researcher to select those participants who would provide rich information and were not handpicked by the school administration to show the school in good light. Sampling is purposive (hence non-probability) since decisions concerning the individuals to be included in the sample are taken by the researcher. The participants are most likely to have certain characteristics relevant to the study.

Two schools were Kendriya Vidyalayas run by the KVS, an organization controlled by the Ministry of Human Resources Development. Three schools were managed by private managements catering to middle income group of clientele. Students were of mixed ability and language and had equal advantage or disadvantage of their socio-economic-cultural background. The infrastructural facilities and profile of teachers and students was more or less the same in these schools. The Kendriya Vidyalayas were following the NCERT text books in all the classes, all the other privately managed schools were adopting textbooks developed roughly on the same content as NCERT textbooks (and CBSE syllabus). The content analysis of the intended curriculum helped the investigator to identity the three topics and to construct an instrument in the form of questionnaire. The questions were constructed from 3 major concepts - food & nutrition, energy and matter. The number of the
items in each major concept was determined according to the number of concepts and sub-concepts within that major concept depicted in the concept maps developed by the researcher. Since the test items were intended to know the conceptual understandings of the learners, all the questions were based on the understanding of the concepts. The purpose of the questionnaire being to find out the conceptualization of students regarding the selected concepts, the items were framed according to the content analysis and concept map developed by the investigator. The items were framed according to the key ideas which are part of the concept map and not according to the syllabus or text books prescribed for elementary level. Also care was taken to frame the items in such a way as to analyse the pre-requisites necessary for development of the subsequent concepts in the topic. For this, many research studies, which focus on the developmental aspect of the concepts were referred.

3.4.2.1. Tool Development

The concept statements appropriate for elementary level provided guidance for item development by setting boundaries around the expectations for these students. Concept statements were developed after consulting many science textbooks meant for elementary students and the derived concept maps.

Decisions about expectations were also based on a review of the literature on student learning (see, for example, Driver et al., 1996). Research on student learning provides information about the complexity of the mental models expected of elementary school students to develop, and it provides with ideas that students find plausible. Misconceptions were used as answer choices to enable the researcher to conduct studies to systematically validate and update existing research on student learning. Careful alignment between targeted knowledge and the answer to the question was made to reduce errors.

The multiple-choice tests are often criticized for assessing student knowledge of just the facts of science, but multiple choice tests also can be constructed that ask students to think through more complex situations and to analyze, explain, and predict phenomena (Tamir, 1989). When clusters of items targeting
the same idea are used together, they can be particularly helpful in assessing students’ understanding of key science ideas. Although a considerable amount of effort is required to construct such test questions, when done well they provide educators with important information about what students know and can do. Smith, Wiser, Krajcik & Coppola (2004) are of the opinion that assessments developed according to these principles will have the following advantages over most large-scale or class-room assessments:

- Assessments can reflect the big ideas underlying the curricula
- Because of the link through learning performance the relationship between curriculum standards and assessment can be more explicit.
- The assessments and their results will help teachers to understand and respond to their students' thinking.

Before developing the final questionnaire, pilot study was undertaken in 2 phases to establish the validity of the questionnaire.

3.4.2.2. Pilot Study

Pilot testing and interviewing provide us with insights about the knowledge students have, how they interpret the wording of the test items, and how they reason through the answer choice options. To improve the validity of the choices of multiple choice items, pilot studies are conducted to identify common student misconceptions and popular belief in constructing the distracters. In the first phase of pilot study, one questionnaire for each class from class 4th to 8th was developed with 25-30 questions from the selected 3 major concepts. The questions were of multiple choice types. The students were asked to choose the most appropriate answer according to them. Few of the questions were two-tiered with the students having to identify reason for their choice in the question of the first tier. The questionnaires were given to 4 experts (1 teacher teaching elementary classes, 2 science teacher educators and one curriculum expert) to establish the content validity. The experts looked at the relationship between the questions and the underlying concepts. Care was taken to focus on what constitutes core concept in the three areas of food, energy and matter.
and to include matching questions according to the cognitive and developmental level of students of each class to assess these concepts. Concept maps were means by which concepts were matched with questions. The concepts were grouped under different areas of each of the major concept. For example concepts were grouped under nutrients, role of food, digestion etc. The questionnaires were revised on the basis of their feedback and executed to a sample of 40 students of each class (4th to 8th) of one branch of Kendriya Vidyalaya. The investigator personally administered the tests in an environment of the classroom. The purpose of the test was conveyed to the students in written form in the questionnaire as well as verbally. The investigator tried to create a non-threatening environment in the classroom. The students were asked not to leave any questions and they were asked to feel free to clarify doubts. They were asked to circle words they did not understand and to tell the researcher if anything is confusing about a question, whether or not they guessed, whether each of the four answer choices is correct or incorrect and why each answer choice is correct or incorrect. To further improve the validity of test items, one-on-one interviewing during pilot testing was conducted during which students were asked for their feedback on the items and their answer choices were compared to the reasons they gave for those answer choices. Pilot testing and interviewing provided the researcher with insights about the knowledge students have, how they interpret the wording of the test items, and how they reason through the answer options. During the pilot, investigator noted down the observations, ambiguity of questions, time taken, and difficulties encountered by the students while attempting the test, so that these ambiguities would be removed for developing the final questionnaires for the three major concepts.

3.4.3. Construction and Administration of Final Questionnaire

The questions in the 3 tools were modified according to the results of the pilot study. The language of some of the questions were modified, few questions were eliminated which were found too difficult for elementary students. The final tool was again validated with the same 4 experts as the pilot study.
The final questionnaires were administered to students of class 4th & 5th, class 6th & 7th, 8th (5th to 9th) in the month of April. The purpose of the test was explained to students. All the questions were read by researcher in classes 4th and 5th. There was no time limit set by the researcher, but permission was sought from principals for 1 hour (2 teaching periods). Most students comfortably finished filling the questionnaire and submitted within 1 hour.

3.4.4. Analysis Design

The analysis was done at two levels:

- general analysis of students’ conceptions of stated concepts
- comprehensive analysis of students’ conceptions

The general analysis consists of simple statistical techniques like mean, standard deviation, difficulty value of concepts and applying one way ANOVA with 3 groups (stage 1, 2 and 3) and chi-square test of significance. Difference within the stage that is between classes 4th and 5th and between 6th and 7th were also tested for significance by chi-square test for all questions and also between stages for select questions which were asked across stages.

The comprehensive analysis was done to see learners’ progression of concepts with their various strands for a detailed understanding. Results were summarized for individual questions grouped under relevant strands. Student’s scientific and alternative conceptions were listed. Wherever students of different stages were presented with the same question, data was presented through graphs.

3.5. Conclusion

This chapter elucidated the various aspects of research used in the present study. The following chapters present the results of major concepts of science i.e. food, energy and matter.