CHAPTER-V

OVERVIEW, CONCLUSION AND SUGGESTIONS FOR EDUCATIONAL IMPLICATIONS AND FURTHER RESEARCH

5.1 SUMMARY

The perusal of research studies on learning scientific concepts, science achievement and identification of errors and diagnosis of misconceptions along with sources of misconceptions is indication of the fact that the focus of researches in science teaching has shifted to diagnostic processes in order to enhance students' understanding and better performance in science achievement. Since there is added emphasis on minimum level of learning at elementary stage to be followed at secondary stage as well, it becomes important to look into the problem of errors and misconceptions contributing to low achievement in science at secondary school stage. The review of related literature pertaining to various socio-psychological variables under investigation provides certain indications that may be briefly summed up as:

- The results of a large number of studies support the fact that females underachieve in comparison to males (Afif, 1977; Sharma, 1981; Smail and Kelly, 1984; Phalachandra, 1989; Reap and Cavallo, 1992; Gupta, 2001 and Aseema and Gakhar, 2004). While the results of the various studies showed that males underachieve in comparison to females in various subjects (Falzon and Sammut, 1976; Mishra, 1986; Vidyapati and Rao, 2003; James & Marice, 2004; Boo, 2005; Steinmayr and Spinath, 2008), some studies show that males and females do not differ in their achievement and for some areas males had better achievement and in other areas females were better (Barua, 1981; Smail and Kelly, 1984; Ventura, 1992; Mishra, 2003; Sungur and Tekkaya, 2003; Orabi, 2007).

- Attitude has been identified as an important correlate of achievement of students. Chen, Hui-Ling (2001); and Mehra (2004) found mathematics attitude to be related to achievement. The findings of some earlier studies (Sarah, 1983; Bandopadhyaya, 1984; Paul, 1986; Darchingpuri, 1989; Kar, 1990; Kumar, 1991; and Nelliappan, 1992) showed significant relationship between scores on scientific attitude and science achievement.

- Some researchers studied the influence of school environment as a factor to promote the academic achievement among students. McLaughling and Drori (2000) and Mehra (2004) concluded that urban atmosphere was more conductive to better achievement than rural
environment. On the other hand Aseema and Gakhar (2004) found rural student to be high achievers. Some researchers found that government, aided and unaided institutions differ significantly in achievement. (Basappa, 2003; Kumaran, 2003; Sobhana, 2004 and Manimekali, 2005). The school environment and organisational features have a significant and positive relationship with achievement of students (Gayani and Aggarwal, 1998; McLaughlin and Drori, 2000; Peecook, 2000; Devi and Mayuri, 2003; Kumaran, 2003; Kalra and Pyari, 2004; and Stewart, 2008).

- Many researches were carried out in various school subjects to identify the naive ideas of students that can create learning difficulties for students and ultimately causing low achievement (Arnaudin and Mintzes, 1985; Boyes and Stainstreet, 1991; Phillips, 1991; Driver, 1993; Lee et al., 1993; Marques and Thompson, 1997; Palmer, 1998). A number of researches have been conducted to identify misconceptions of various concepts of physics (Gunstone and White, 1981; Tiberghien, 1985; Halloun and Hastenes, 1992; Hapkiewicz, 1992; Grayson et al., 1995; Graham and Peek, 1997, Chen and Lin, 2003; Hancer and Durkan, 2008). Many researchers tried to identify the misconceptions held by students in learning of chemistry concepts (Osborne and Cosgrove, 1983, Clough and Wood Robinson, 1985, Ben-zvi, 1986; Cross, 1986; Furio, 1987; Hand and Tregast, 1991; Hapkiewicz, 1991; Bodner, 1991; McCoy, 1991; Ross and Munby, 1991; Griffith and Preston, 1992; Abraham, Williamson and Westbrook, 1994 Nakhle and Krajcik, 1994; Huddle and Pillay, 1996; Ebenezer and Gaskell, 1995; Voska and Heikkinen, 2000; Tan, 2002; Demerouti, 2004; Sarikaya, 2004). Misconceptions were identified in learning of various biological concepts by some studies (Fisher, 1985; Trowbridge and Mintzes, 1985; Haslam and Tregast, 1987; Dreyfus and Jungwirth, 1989; Amir and Tamir, 1990; Anderson, Sheldon and Dubey, 1990; Westbrook and Marek, 1991; Pachaury, 2001; Ross, 2004; Yen et al. 2004; and Shaw et al., 2008) while some studies tried to identify the naive conceptions (ideas) of students about various mathematical concepts (Odom, 1995; Berthelsen, 1999; Tatsuoka, 2000; and Tiley, 2003).

- Errors made by students were identified by some researches affecting the achievement of students (Raman, 1989; Kousathana and Tsaparlis, 2002; Shook, Linda Jean, 2003; Bhise, Desetty and Patnam, 2004; Bataineh, 2005; and Afamasaga, 2007 and Kumar, 2007).

- Many researchers found various causes of misconceptions among students. Some studies revealed that misconceptions were related to the nature of concepts or the lack of knowledge of the concepts (Longden, 1982; Hibert and Wearne, 1983; Engel Clough and driver, 1986; Mason and Tooley, 1992; Leach et al. 1995; Lord and Marino, 1993; Graham and Berry, 1997; Rowland, Graham and Berry, 1998; Hershey, 2004; Sindhu and Sharma, 2004). Certain studies concluded that misunderstandings/misconceptions are perpetuated by teachers.
(Barass, 1984; Kinderfield, 1991; Debra, 2000; Sanders, 2006). Textbooks were also found to be the sources of misconceptions by some researchers (Barass, 1984; Choo, Hee-Hyung et al. 1985; Sanger, 1997; Debra, 2000). The results of some studies showed that misconceptions were due to the fact that students tended to confuse the terms (Hardt and Paula, 1997; Chandrasegaran, Treagust and Mocerino, 2008).

- Experimental treatment was given in many researches to help the students having misconceptions and concluded that it is difficult to overcome the misconceptions even after the course (Fredette and Clement, 1981; Adeniyi, 1985; Dupin and Johsua, 1987; Griffiths et al., 1988; Hartman, 1996; Hill, 1997). Some studies were conducted to discover the impact of remedial teaching programmes for correcting/reducing common errors and misconceptions (Hand, 1989; Raman, J., 1985; Seymour and Longden, 1991; Setlage, 1994; Berry, 2000; Li, 2000; Ozkam, 2001; Eryilmaz, 2002; Lin, 2004; Demirciolgu, 2005; Kutluay, 2005; Sarikaya, 2007; Chandrasegaran, Treagust and Moscerino, 2008; Klymkowsky and Gravin, 2008).

A glimpse of review of a large number of studies into students' alternative conceptions, carried over past three decades, indicates that these studies investigated various aspects of science learning at different stages of school education but only a few studies are in the field of biology and even fewer in the subject area of environment. Further, there is paucity of researchers in the area "errors and misconceptions in learning of scientific concepts" in Indian Context. Hence the present study is an endeavour in this direction to provide empirical evidence with regard to problems in learning of scientific concepts with objectivity and also to identify the students' misconceptions and their underlying sources. In the light of on going researches in science teaching and learning and emerging needs of teaching science with scientific approach, the research problem was undertaken as stated below:

**A STUDY OF ERRORS AND MISCONCEPTIONS IN SCIENCE AT SECONDARY SCHOOL STAGE**

**Significance of the Study**

Science education has been given utmost important in educational programmes to equip the young learners with skills that will enable them to be rational, progressive and forward looking citizens of a nation in the era of
science and technology. Still, there is more emphasis on rote learning, while learning with understanding has been neglected in the existing curricular transaction process. Hence the findings of the study are expected to provide an insight into the learning of scientific concepts in a scientific method by identifying errors and misconceptions in science learning and enhance the probability of better achievement.

The methodology adopted in the identification of errors and misconceptions will provide a lead to future researchers, not only in the area of science, but in other subject areas as well. Therefore, it is expected that the results of the present study will open new vistas for researchers to provide new direction in teaching-learning process along with providing some concrete suggestions for educational practitioners to adopt such strategies in school education. Moreover, the psychological principles underlying three tier testing in concept achievement will provide a new orientation to evaluation of learning outcomes of students in a more comprehensive manner. Assessing students' misconceptions is very important for effective learning.

The identification of students' misconceptions in this study and the approximate student age at which they develop conceptual understanding will be of use to teachers by acting as a guide for what to expect from the students in teaching learning process.

Also, the findings of the study will have an implication for teachers' education programmes, both pre-service and in-service, in order to guide students to perform in science with excellence.

Objectives of the Study

(i) To construct and standardize Concept Achievement Test (CAT) in science for secondary school students.

(ii) To find out the level of performance of secondary school students on Concept Achievement Test (CAT) in science.

(iii) To find out the percentage of students who committed errors on Concept Achievement Test (CAT) in science.

(iv) To identify the sources of errors and misconceptions and determine the percentage of students in different types of errors and misconceptions on Concept Achievement Test (CAT) in science.
(v) To study pattern of errors and misconceptions on Concept Achievement Test (CAT) in science in relation to gender.

(vi) To study pattern of errors and misconceptions on Concept Achievement Test (CAT) in science among secondary school students in relation to location.

(vii) To study the pattern of errors and misconception on Concept Achievement Test (CAT) in science among secondary school students in relation to academic achievement.

(viii) To study the patterns of errors and misconceptions on Concept Achievement Test (CAT) in science in relation to scientific attitude.

Hypotheses

1. There will be no significant gender differences in pattern of errors and misconceptions and sources of errors and misconceptions on Concept Achievement Test (CAT) in science, committed by secondary school students.

2. The rural secondary school students will differ from urban secondary school students in their pattern of errors and misconceptions on Concept Achievement Test (CAT) in science.

3. The students with favourable scientific attitude will differ from students with unfavourable scientific attitude in their pattern of errors and misconceptions on Concept Achievement Test (CAT) in science.

4. The students with high academic achievement will differ from students with low academic achievement in their pattern of errors and misconceptions on Concept Achievement Test (CAT) in science.

Delimitations of the Study

The present research study was delimited in the following manner.

1. Only government secondary schools of Punjab, affiliated with PSEB constituted the universe for the study.

2. The Concept Achievement Test (CAT) in science was delimited to the unit of environment of science textbook prescribed for 9th class students.

3. Only conceptual issues were taken up for construction of Concept Achievement Test (CAT) in science. The numerical aspects of any kind of concept were not included in the study.

4. The identification of errors and misconceptions, as per students' performance on Concept Achievement Test (CAT) in science was
determined through descriptive method and no remedial instructions were provided to students.

Operational Definition of Terms

The key terms used in the study may be operationally defined as under:

- **Error:** Error is the state of departing from truth or it is the state of being inaccurate/wrong in behaviour (21st Century Dictionary, 2004), taken as wrong answers given to the multiple choice test items (first tier) of Concept Achievement Test (CAT) in science because multiple choice test is the most frequently used tool for detecting most frequently appearing errors (Rollnick and Mahooana, 1999). Students make many types of errors in tests but all errors are not misconceptions as some errors may be objectively false conceptions. Errors may be due to mistakes, lack of knowledge and misconceptions among students (Eryilmaz and Surmeli, 2002; Haki, 2005; and Kutuluay, 2005).

- **Objectively False Conceptions:** The objectively false conception is the gap between the errors and misconceptions, taken as incorrect answer in first tier (error) and incorrect reason in second tier of Concept Achievement Test (CAT) in science. Objectively false conceptions may produce misconceptions (Wikipedia, The Free Encyclopedia, 2008). In conveying a concept the students, having objectively false conceptions, may give the incorrect answers due to lack of knowledge or due to misconceptions.

- **Misconceptions:** These refer to intuitive ideas that students have constructed for themselves as a result of experiences with their physical environment, popularly known as students’ conceptions, children’s science alternative conceptions or alternative frame works (Gilbert and Watts, 1983), and as private concepts, naive theories and half truths (Mestre, 1987) and as naive conceptions or naive knowledge (Reiner, Slotta, Chi and Resnick, 2000) and as commonsense beliefs (Hestenes, Wells and Swackmer, 1992). All the errors are not misconceptions, since misconceptions happen when a person shows confidence in the objectively false concept (Wikipedia, The Free Encyclopedia, 2008) and can be assessed by referring to incorrect answer in first tier, incorrect reasoning in second tier and confidence shown by the student in third tier in Concept Achievement Test (CAT) in science.

Methodology

Descriptive method of research was used in the conduct of the present study: The study was completed in two phases:-
Phase I: Construction and Standardization of Concept Achievement Test (CAT) in Science

The construction and standardization of the Concept Achievement Test (CAT) in science was based on the methodologies devised and used by researchers to study misconceptions and errors in different subjects/specific area of content matter (Adeniyi, 1985; Trowbridge and Mintzes, 1988; Amir and Tamir, 1990; Odom et al., 1995; Griffard and Wandersee, 2001; Ozkam, 2001; Eryilmaz and Surmeli, 2002; Cataloglu, 2002, Ozay and Oster, 2003; Schmidt et al., 2003; Sindhu and Sharma, 2004; Cetin et al., 2004; Demircioglu et al., 2005; Haki, 2005; Kutluay, 2005).

Concept Achievement Test (CAT) in science in the content area of environment was constructed and standardized by the researcher to include the concepts of: "adaptations, habitat, biosphere, ecosystem, food chain and food web, functions of ecosystem, biomass and biodiversity", on the basis of PSEB prescribed science text book.

The preliminary draft of the test consisting of 53 test items was to be responded on three tiers. First tier includes multiple choice items, having one correct answer and three distracters and requires students to select correct answer. Second tier requires students to write reason of the response. Third tier asks students about their confidence for the answer in first tier and reason in second tier. Total achievement score of each student was calculated according to the students' multiple choice item scores, reasoning part scores and the confidence level scores together. The scoring pattern in this test was as under:

<table>
<thead>
<tr>
<th>First Tier</th>
<th>Second Tier</th>
<th>Third Tier</th>
<th>Total Scores on Concept Achievement Test (CAT) in Science</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (correct)</td>
<td>1 (correct)</td>
<td>1 (confident)</td>
<td>1</td>
</tr>
<tr>
<td>1 (correct)</td>
<td>0 (incorrect)</td>
<td>0 (not confident)</td>
<td>0</td>
</tr>
<tr>
<td>1 (correct)</td>
<td>1 (correct)</td>
<td>0 (not confident)</td>
<td>0</td>
</tr>
<tr>
<td>0 (incorrect)</td>
<td>1 (correct)</td>
<td>1 (confident)</td>
<td>0</td>
</tr>
<tr>
<td>0 (incorrect)</td>
<td>0 (incorrect)</td>
<td>0 (not confident)</td>
<td>0</td>
</tr>
</tbody>
</table>

Three types of scores were analyzed for right answers as given in table 5.2:
Table 5.2
Scoring Pattern of Right Answers on Concept Achievement Test (CAT) in Science

<table>
<thead>
<tr>
<th>Pattern of Correct Answers</th>
<th>First Tier</th>
<th>Second Tier</th>
<th>Third Tier</th>
<th>Scores of Correct Answers on CAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correct Answers</td>
<td>1 (correct)</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>False Positive</td>
<td>1 (correct)</td>
<td>0 (incorrect)</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>True Conception</td>
<td>1 (correct)</td>
<td>1 (correct)</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Lack of Knowledge</td>
<td>1 (correct)</td>
<td>1 (correct)</td>
<td>0 (not confident)</td>
<td>0</td>
</tr>
<tr>
<td>Complete Understanding of Concept</td>
<td>1 (correct)</td>
<td>1 (correct)</td>
<td>1 (confidence)</td>
<td>1</td>
</tr>
</tbody>
</table>

**Correct Answers:** The number and percentage of the correct answers to the first tier for each item and total correct answers of the students for the first tier of test were calculated.

**True Conceptions:** The number and percentage of the correct answers to the first two tiers (if student has given correct answer in first tier and correct reason in second tier) for each item and total correct answers of the students for the first two tiers of the test were calculated.

**Complete Understanding of Concept:** It is important to say that even if a student's answers for the first two tiers were correct, it was not accepted unless the students clarified his/her confidence in the third tier. If the students said, “Yes, I am sure” it was accepted true and if the student said, “No, I am not sure” it was accepted false. The percentage of the correct answer to all the three tiers for each item and total correct answers of the students for all the three tiers were calculated.

In this type of the test the proportion of right answers decreases as the tier of the test increases. The difference (decrease) in the proportion of the correct answers in one tier (correct answers) and two-tier test (true conceptions) gives false positives (the correct answers given by students who do not have scientific conception) and the difference (decrease) in the proportion of the correct answers in two-tier-test (true conceptions) and three-tier test (complete understanding of concept) attributes to lack of knowledge.
because the right answers can not be accepted unless the student shows his confidence in the third tier.

Three types of scores were analyzed for wrong answers as given in table 5.3:

<table>
<thead>
<tr>
<th>Error Patterns</th>
<th>First Tier</th>
<th>Second Tier</th>
<th>Third Tier</th>
<th>Scores of Wrong Answers on CAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Error</td>
<td>0 (incorrect)</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Mistakes</td>
<td>0 (incorrect)</td>
<td>1 (correct)</td>
<td>1 (confident)</td>
<td>0</td>
</tr>
<tr>
<td>Objectively False Conception</td>
<td>0 (incorrect)</td>
<td>0 (incorrect)</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Lack of Knowledge</td>
<td>0 (incorrect)</td>
<td>0 (incorrect)</td>
<td>0 (not confident)</td>
<td>0</td>
</tr>
<tr>
<td>Misconception</td>
<td>0 (incorrect)</td>
<td>0 (incorrect)</td>
<td>1 (confident)</td>
<td>1</td>
</tr>
</tbody>
</table>

**Errors:** The percentage of the wrong answers to first tier was counted and also the number of errors for each student for first tier was calculated.

**Objectively False Conceptions:** The percentage of the wrong answers according to first two tiers (if student has given wrong answer in first tier and wrong reason in second tier) were estimated and also the number of the wrong answers for each student for first two tiers were calculated.

**Misconceptions:** It is important to say that even if a student's choice selection for the first two tiers indicated wrong answer it was not accepted as a misconception unless the student indicated his/her confidence in the third tier. The percentage of the misconceptions in terms of responses to all the three tires was calculated and the number of misconceptions for each question was calculated.

In this type of the test the percentage of students having wrong answers decreased as the tier of the test was increased. The difference (decrease) in the percentage of the students having wrong answers according to one tier test (errors) and two-tier test (objectively false conceptions) was due to *false negatives* (the percentage of students who gave wrong answers to the first tier of any item and correct reason to the second tier of that item).
The percentage of *false negatives* should be less than 10% (Hestene and Halloun, 1995).

Similarly, the percentage of wrong answers decreased as the tier of the test increased from two-tier to three-tier. The difference (decrease) in the percentage of students having wrong answers according to two-tiers (objectively false conceptions) and three-tier test (misconceptions) was due to lack of knowledge.

Therefore, it can be stated that after the identification of errors and prior to the identification of misconceptions: mistakes, objectively false concepts and lack of knowledge may emerge in between and are to be taken into account.

The preliminary draft of the test was shown to the judges (the teachers teaching science subject in schools and language experts) for content validation to assess whether the items adequately represent a performance domain or construct of specific interest. Then the test items were evaluated by finding the difficulty value of items. On the basis of the indices of item difficulty (0.16-0.25), 23 items were discarded and 30 items were selected for the final draft of Concept Achievement Test (CAT) in science.

Reliability of final draft of the test was calculated by calculating Kuder-Richardson reliability coefficient. The reliability of the test came out to be 0.79. The content validity of the Concept Achievement Test (CAT) in science was established.

**Interview Schedule for Identification of Sources of Misconceptions**

An interview schedule was developed for the identification of sources of misconceptions. Scoring of the interviews was qualitative. The various sources of misconceptions were categorized as suggested by Comins (1993).

**Phase II: Field Work**

After the construction and standardization of the (CAT) Concept Achievement Test in science the survey work was carried out in the following manner:
Tools

Following tools of research were used for the collection of data:

1. **Concept Achievement Test** constructed and standardized by researcher herself.
2. **Interview schedule** for identification of sources of misconceptions.
3. **Scientific Attitude Scale (SAS)** developed and standardized by Gakhar and Kaur (1995) was used for measuring the attitude relevant in science education.
4. **Academic Achievement** of secondary school students was taken on the basis of their 8th class examination held by PSEB.

Sampling

A sample of 912 students of 9th class studying in high and senior secondary government schools was selected by randomly selecting 33 schools from seven districts of Punjab namely, Patiala, Ropar, Ludhiana, Bathinda, Mansa, Fatehgarh Sahib and Sangrur for identifying the errors and misconceptions in science. Out of 912 students 313 students (high achievers and low achievers) were interviewed for identification of sources of errors and misconceptions.

Administration of Tools

The field work was completed within two months by visiting the selected schools and administering the tools of research i.e. Concept Achievement Test (CAT) in science, Scientific Attitude Scale (SAS). The academic achievement of students (annual middle standard examination marks in percentage) was noted from school record.

Statistical Treatment of the Data

Descriptive statistics was used to explain the performance of students on Concept Achievement Test (CAT) in science. The percentage and number of students who committed errors for all the seven concepts were calculated and classified to explain the patterns of errors and misconceptions committed by students.

The errors, misconceptions and their sources were analyzed in terms of their distribution across gender, location, scientific attitude and academic achievement groups.
The t-test was applied to test the significance of mean difference in the performance of secondary school students on Concept Achievement Test (CAT) in science.

5.2 CONCLUSIONS

In the light of the results of the present study with regard to performance of the students on Concept Achievement Test (CAT) in science following conclusion may be drawn:-

Level of Performance in Concept Learning in Science

- The achievement of secondary school students of Punjab on Concept Achievement Test (CAT) in science is moderate.
- A large number of secondary school students gave correct answers in the concept area of 'adaptations', while a majority of secondary school students gave correct answers for the concept areas of 'habitat', biosphere, 'ecosystem', 'food chain and food web' and 'functions of ecosystem' respectively. Few students were able to give correct answers in the concept area of 'biomass and biodiversity'.
- Majority of the secondary school students have true conceptions in the concept areas of 'adaptations', 'biosphere' and 'ecosystem'. Nearly majority of the students have true conceptions in the concept areas of 'food chain and food web' and 'functions of ecosystem', while few students' conceptions were true in the concept area of 'biomass and biodiversity'.
- Few secondary school students have complete understanding in the concept areas of 'biomass and biodiversity' as well as 'adaptations'. Nearly majority of the secondary school students have complete understanding in the concept areas of 'food chain and food web' and 'functions of ecosystem', while majority of students have complete understanding of the concept areas of 'habitat', 'biosphere' and 'ecosystem' on Concept Achievement Test (CAT) in science.
- There is no significant gender difference in mean achievement of secondary school students in Concept Achievement Test (CAT) in science.
• The urban secondary school students have significantly higher performance on Concept Achievement Test (CAT) in science as compared to their rural counterparts.

• The secondary school students with high academic achievement have significantly higher performance on Concept Achievement Test (CAT) in science as compared to their low achiever counterparts.

• The secondary school students with favourable scientific attitude perform significantly higher than their counterparts with unfavourable scientific attitude on Concept Achievement Test (CAT) in science.

The level of performance on Concept Achievement Test (CAT) in science is directly/positively affected by achievement and attitude. These results are in line with Sarah (1983), Bandopadhyaya (1984), Paul (1986), Darchingpuri (1989), Kar (1990), Kumar (1991), Nelliappan (1992).

The gender has no role in the performance on Concept Achievement Test (CAT) in science. The findings are similar to the results of Barua (1981), Smail and Kelly (1984), Ventura (1992), Misra (2003), Sungur and Tekkaya (2003), Orabi (2007).

Urban secondary school students have better achievement on Concept Achievement Test (CAT) in science. Similar results were shown by McLaughling and Drori (2000) and Mehra (2004).

Errors on Concept Achievement Test (CAT) in Science

• A large number of secondary school students committed errors in the concept area of 'biomass and biodiversity'. Majority of the secondary school students committed errors in the concept areas of 'habitat', 'biosphere', 'ecosystem', 'food chain and food web' and 'functions of ecosystem' respectively, while nearly majority of the secondary school students committed errors in the concept area of 'adaptations'.

• The secondary school girls, in large number, as compared to boys, committed errors in the concept areas of biosphere and 'ecosystem' which support the fact that secondary school girls underachieve in relation to males.
• The rural secondary school students committed more errors in comparison to urban secondary school students in the concept areas of 'habitat', 'ecosystem' and 'food chain and food web'.
• Low achiever secondary school students committed significantly more errors in all the areas of Concept Achievement Test (CAT) in science.
• The secondary school students with unfavourable scientific attitude committed more errors in the concept areas of 'adaptations', 'habitat', 'food chain and food web', 'functions of ecosystem' and 'biomass and biodiversity'. Errors were identified by Raman (1989) in the area of calculus; Kousathana and Tsaparlis (2002) in the subject of chemistry; Shook and Jean (2003) in the area of science; Bhise, Desetty and Patnam (2004) among secondary school students; Bataineh (2005) about infinite articles; and Afamasaga (2007) about mathematics.

**Objectively False Conceptions on Concept Achievement Test (CAT) in science**
• A large number of secondary school students have objectively false conceptions in the concept area of 'biomass and biodiversity'. Majority of the secondary school students have objectively false conceptions in the concept areas of 'habitat', 'ecosystem', 'food chain and food web' and 'functions of ecosystem' while, nearly majority of the secondary school students have objectively false conceptions in the concept areas of 'adaptations' and 'biosphere'.
• Significantly more number of secondary school girls have objectively false conceptions in only one concept area i.e. 'functions of ecosystem'.
• Comparatively more number of rural secondary school students' conceptions are objectively false in the concept areas of 'biosphere', 'ecosystem', 'food chain and food web'. While, in the concept area of 'biomass and biodiversity' more number of urban secondary school students' conceptions are objectively false.
• As far as low achiever secondary school students are concerned they have objectively false conceptions in all the areas of Concept Achievement Test (CAT) in science. Therefore, the secondary school students with high academic achievement significantly have less
objectively false conceptions as compared to their high achiever counterparts.

- The secondary school students with unfavourable scientific attitude significantly have more objectively false conceptions as compared to their counterparts with favourable scientific attitude on Concept Achievement Test (CAT) in science.

Objectively false conceptions were identified by some researchers in the area of photosynthesis and respiration by Hill (1997), simple electric circuit by Haki (2005), geometric optics by Kutuluay (2005), and genetics by Shaw et al (2008).

**Misconceptions on Concept Achievement Test (CAT) in science**

- The majority of the secondary school students has misconceptions in the concept area of 'biomass and biodiversity', while nearly majority of the secondary school students have misconceptions in the concept area of 'functions of ecosystem'. Few secondary school students have misconceptions in the concept areas of 'adaptations', 'habitat', 'biosphere', 'ecosystem' and 'food chain and food web' respectively.

- In the concept area of 'functions of ecosystem' secondary school girls have more misconceptions but significantly there is not any gender difference in the mean misconceptions of secondary school students on Concept Achievement Test (CAT) in science.

- There is no significant difference in the mean misconceptions of rural and urban secondary school students; however, rural students have significantly more misconceptions in the concept areas of 'biomass and biodiversity' while urban secondary school students have more misconceptions in the concept area of 'functions of ecosystem' as compared to their counterparts.

- There is no significant difference in the mean misconceptions of secondary school students with favourable and unfavourable scientific attitude on Concept Achievement Test (CAT) in science.

Misconceptions were found by Pachaury (2001) about respiratory organelles of invertebrate animals; Ross (2004) about concept of animals;
Sources of Errors on Concept Achievement Test (CAT) in Science

- The secondary school students committed errors due to mistakes (inconsistent answers), lack of knowledge and misconceptions.
- The secondary school students committed mistakes in all the concept areas of environment, which are mainly due to false positives (the percentage of students who gave correct answer to the first tier of any item but wrong reason in the second tier of that item i.e. do not have scientific conception) and false negatives (the percentage of students who gave wrong answers to the first tier of any item and correct reason to the second tier of that item).
- The percentage of false negatives is estimated to be 2.54% and percentage of false positives is estimated as 7.75%. These values are evident enough for the validity of the Concept Achievement Test (CAT) in science according to the explanation of Hestenes and Halloun (1955). In their explanation, they reported that the percentage/probabilities of false negatives and false positives should be less than 10%. It can be fulfilled to minimize the probability of false negatives by producing powerful distracters. However, minimizing the probability of false positives is not as easy as minimizing the probability of false negatives because of some students who answer the questions on the test by chance.
- There is no significant difference in the mean mistakes, lack of knowledge and misconceptions among boys and girls on Concept Achievement Test (CAT) in science.
- The urban secondary school students are not significantly different in mean mistakes lack of knowledge as well as misconceptions on Concept Achievement Test (CAT) in science.
- Significantly academically low achievers have more mistakes, lack of knowledge as well as misconceptions as the sources of errors on Concept Achievement Test (CAT) in science as compared to their academically high achiever counterparts.
• It is found that students with favourable scientific attitude have significantly more mean mistakes, lack of knowledge and misconceptions as the sources of errors as compared to their counterparts on Concept Achievement Test (CAT) in science.

• These results show that even the high achieving student had lack of knowledge and they made mistakes too. Misconceptions persist in high achieving students, although they get good marks.

• In all the seven concepts in Concept Achievement Test (CAT) in science in the area of environment the percentage of students having misconceptions was more than 10% which is the alarming situation. There are 20-30% secondary school students who have misconceptions in the concept areas of 'adaptations', 'habitat', 'biosphere', 'ecosystem', 'food chain and food web'. Also, there are 30-40% secondary school students who have shown misconceptions in the concept area of 'functions of ecosystem' and nearly majority of secondary school students have misconceptions in the concept area of 'biomass and biodiversity'.

• The percentage of students having lack of knowledge attracts attention in all the seven concept areas. The maximum number of students was having errors and misconceptions in the concept area of 'biomass and biodiversity'. It was seen that maximum number of students gave wrong answers due to lack of knowledge in the concept area of 'adaptations'. A number of studies conducted earlier have identified sources of errors in the subject area of biology by Hill (1997); physics by Eryilmaz and Surmeli (2002); geometric optics by Chen and Lin (2003); organic chemistry by Sindhu and Sharma (2004); geometric optics by Kutluay (2005); geometric optics by Haki (2005); physics by Kucukozer and Kocakulah (2007); biology by Klympowsky and Gravin (2008).

Sources of Misconceptions

On the basis of interview with secondary school students having high or low level of performance on Concept Achievement Test (CAT) in science nine types of sources of misconceptions were identified:
Confusion; Language Imprecision; Overgeneralization; Misclassification; Misidentification; Erroneous Reasoning; Incomplete Understanding of the scientific process

Mester (1982), Tyson, Treagust and Bucat (1999), Debra (2000) and Ross (2004) found language imprecision to be the source of misconceptions; Pearson and Hughes (1988), Hardt and Paula (1997) found confusion as the source of misconceptions; Kesidou and Duit (1993), Lord and Marino (1993), and Graham and Berry (1997) found incomplete understanding of scientific process to be the source of misconceptions.

Common Misconceptions on Concept Achievement Test (CAT) in Science

Following misconceptions (Content wise) were identified:

(i) Adaptations

Habitats are called adaptations; when plants and animals change their habitat it is called adaptation; biome is a habitat; adaptation is adjustment; adaptation is a place which is best suited for plants and animals to live.

Xerophytic plants do not require water; xerophytic plants are grown at places where water is neither deficient; deserts are the places where water is available in abundance; xerophytes grow on marshy places.

Mesophytic plants have reduced leaves which help in the growth and development of the plant; the stems of mesophytic plants are solid and freely branched because they get more amount of water and minerals as compared to other plants; mesophytic plants grow at place where water is available in abundance; the number of stomata is more in mesophytic plants which helps is making their stems strong; mesophytic plants absorb water from soil to make their stems solid.

Sometimes lotus grows on land but mostly grows in water; cactus and rose are hydrophytic plants; bipedality is not the feature of terrestrial adaptation; terrestrial animals need fins for flying; fins and feathers are equivalent; modification of head and foot are not found in terrestrial animals; no animal on this earth is bipedal; dolphin lives in sea only; dolphin respires through its lungs in water; lizard has modifications to live in water; birds make their nests on trees so they have arboreal mode of adaptation; birds make their own food; birds have fins which help them to fly.
(ii) Habitat

Environment consists of air only because air purifies the environment, moreover, animals and plants can't live without it; animals and their environment are biotic components; environment refers to abiotic component because all the organisms live in it; in ecology only microorganisms live; habitat of plants and animals can only be land because they can live only on land; plants and animals are not adapted to live in water and air; habitat of plants and animals can only be water and land.

(iii) Biosphere

Biosphere has two components: Who can breath and who can't breath; biosphere has three components i.e. biotic, abiotic and animals; biosphere has four components i.e. sun, plants, herbivores and carnivores; biosphere has two components i.e. water and land; carbon dioxide, light and minerals are biotic components; a plant gets food from symbiotic relationship; a plant depends upon biotic components only for its survival; symbiotic relationship has biotic and abiotic components; symbiotic relationship does not require moisture and oxygen for its survival.

Temperature, sunlight and moisture are the biotic factors; these are edaphic factors; green Plants are called producers because animals get leaves from them; green plants are called herbivores because herbs are also green in colour; herbivores are green coloured plants; green plants are called producers because we get fruits, vegetables, medicines and wood from them; plants grow by their own so they are called producers.

Green plants are living, therefore they are called producers; green plants produce more plants so are called producers; green plants are called producers because herbivores eat them; plants get chlorophyll from sun and grow by their own.

(iv) Ecosystem

Rivers and forests are the terrestrial ecosystem; only forests have terrestrial ecosystem; rivers and deserts are the terrestrial ecosystems; park is artificial ecosystem because man feels happy and peaceful in park; forest is the artificial ecosystem because all the animals live in forests; ecosystem is applicable in forests only; mountains have artificial ecosystem because there the temperature is high and oxygen is in less quantity.
(v) Food Chain and Food Web

Consumers consume the producers directly; consumers consume the producers indirectly; consumers consume producers neither directly nor indirectly; those organisms which feed both on plants and animals are called carnivores e.g. grass deer Lion; carnivores get food from plants and meat from animals; insectivores get food both from plants and animals; plants and animals get food from omnivores; consumers which feed directly on plants for their food are called carnivores.

The consumers which feed directly on plants are called decomposers; autotrophs depend upon producers for food; deer is the example of decomposer because it feed both on herbivores and carnivores; bacteria and fungi are the adaptations for decomposers; decomposers are plants; decomposers are dangerous; in a food chain animals/organisms depend directly on each other; food chain is eaten by living beings.

Grass is a herbivore; deer is a decomposer; food chain is always in forests; in a food chain first come herbivore then decomposer and then carnivore; confusion between food chain and food web; a food web has 5 or 6 number of food chains only; food web is a kind of web in which living beings are trapped.

(vi) Functions of Ecosystem

Soil, moisture, light and air are the organic compounds that help in the formation of organisms; formation of organic compounds is not possible without soil, moisture, light and air; carbohydrates, temperature and sunlight are the organic compounds; biological magnification creates new scientific changes in the environment; biological oxidation is the process of digestion of poisonous substances.

When the organisms at higher trophic level get food its oxidation is done; in biological diversification, organisms get poisonous substances; in a food chain plant → Deer → Lion, lion has more energy then deer and plants because deer eats plants and lion eats deer, so all the energy goes to lion; all have equal energy because they all get energy from sun; plants have more energy because they suck photosynthesis.
Plants have more energy because all the animals eat plants; lion is at the last trophic level of food chain so has maximum energy; plants provide so many facilities to animals, that is why they have more energy; all the nutrients and materials are present in plants so have more energy; all the organisms will die without plants so they have more energy; proteins, nitrogen, Sulphur are inorganic substance because they are not made up of carbon; the percentage of nitrogen in the atmosphere is 78% because of increasing population and decreasing trees in the world; nitrogen fixation, nitrification and ammonification are the factors which are obtained by nitrogen cycle.

(vii) **Biomass and Biodiversity**

In ecosystem herbivores have maximum energy; herbivores e.g. elephants have maximum energy so they have maximum biomass; carnivores consume meat so their biomass is maximum; biomass of lion is more as compared to other animals; herbivores are at first tropic level; biomass of decomposers is maximum because they decompose the organisms slowly; carnivores have maximum biomass because they are physically very strong and they possess the biomass of producers and consumers; the decomposers cannot die so easily so they have maximum biomass.

Plants occupy so much of space on this earth so have maximum biomass; for conservation of species animal banks are made; gene banks are the best banks; blood banks are made for the conservation of species because blood is essential for our body; DNA banks are made for the conservation of species.

Similar misconceptions have been found by Adeniyi (1985) about food chain, energy flow and carbon cycle; Gallegos et al (1994) in the concepts of food web and relationship with ecosystem; Leach et al (1995) in the concepts of functions of ecosystem; Ozkam (2001) about ecological concepts of environment, ecosystem, decomposers, food chain and food web; Cetin (2004) about energy flow, food chain, food web and recycling of matter.
5.3 SUGGESTIONS FOR EDUCATIONAL IMPLICATIONS AND FURTHER RESEARCH

Keeping in view the need and scope of the study following suggestions may be laid down for educational implications and further research.

5.3.1 Suggestions for Educational Implications

In the light of the findings of the present study regarding errors and misconceptions in science learning among secondary school students, following implications emerged that can be used by teachers to improve the delivery of science education.

1. The results of the study showed that students made errors, due to mistakes, lack of knowledge or due to misconceptions. These misconceptions resist to change and obstruct the learning process. The teachers are required to take students' misconceptions into account. The more the teachers know about their students' misconceptions the more guidance they will be able to provide them to learn. This could contribute to the professional development of science teachers. Smith and Anderson (1993) and Lawrenz (1986) advocated that during (preservice and inservice) teacher education programmes the teachers should be given chances to identify misconceptions held by the pupils in their classrooms.

2. In the study, it is found that the students having higher scores on the Concept Achievement Test (CAT) in science have misconceptions in some aspects as compared to the students with low scores. Therefore, the teachers should consider that even if the students have high scores in the examination, they may have as many misconceptions as the students with low scores. In the interviews, it was seen that even if the students were academically high achievers, they had little or no understanding of the concepts of environment. For example, when the students were asked to count the number of food chains in a food web, they explained that their teachers do not ask such questions. They only memorize but do not understand the concepts scientifically. Tytler (2002) also argued that deep rooted conceptions can offer a serious barrier to effective teaching. Therefore teachers should emphasize on the conceptual understanding of the students. The constructivist approach is important in terms of encouraging students to think about the scientific concepts and their conceptions.

3. Teachers can use the Concept Achievement Test (CAT) in science for formative evaluation to assess the misconceptions of the 9th class students about the unit of environment. The findings of this study could facilitate teachers in their planning and implementation of relevant measures to reduce the incidence of students' misunderstandings about the concept of environment. A teacher should focus on students cognitive level to eliminate misconceptions, because most of the
students in high schools and all students in elementary and junior high schools are in concrete levels; therefore, the major focus of instruction for those students should link between concept and concrete experiences and expect difficulties on linking concrete experiences to abstract concepts because any science concept has a relationship with other concepts, so students have to link the ideas and other concepts. When students create this linkage in their mind, they are going to correct their misconceptions and develop meaningful understanding of new concept (Turkman and Usta, 2007). Abraham, Williamson and Westbrook (1994) suggested that if we want to decrease misconceptions, we have to increase experiences. Therefore, the highest priority for science teacher should be to pay attention to cognitive development with the help of activities because experience makes concepts more believable and understandable (Marek, 1986).

4. The findings of the study show that multiple choice tests and also two tier tests overestimate the misconceptions of the students. For, they do not take into account the mistakes and lack of knowledge among students. Moreover, both types of tests also overestimate the correct answers of students. Therefore, to avoid from mistakes and lack of knowledge causing the wrong answers of the students, teachers should use three-tier tests to investigate the misconceptions of the students. They should consider that results of the multiple-choice tests or even two-tier tests can be misleading while investigating the misconceptions of the students. Therefore, teachers and researchers should prefer three tier tests.

5. Identification of the students’ misconceptions in science for the unit of environment by Concept Achievement Test (CAT) in science can give some feedback to the textbook editors. They can use more examples and simple questions dealing with the misconceptions instead of complex situations and questions. Students’ misconceptions and alternative ideas can be taken into consideration by curriculum developers and remediation techniques of them should be designed. If these techniques can be combined with small group work with demonstration and appropriate hands-on activities, they should be very powerful methodology for science classrooms.

6. Classroom instructions may be organized in a manner that takes into account students’ conceptions similar to the ones that have been identified in this study. When directly confronted with conceptions that students realize are not scientifically acceptable and through discussion with the teacher and with peers in small groups, students may lead to arrive at more fruitful understanding of concepts of environment. For example, discussions about adaptations in plants and animals will help to remove various misconceptions generated due to confusion and language imprecision. Earlier, Engel Clough and Wood Robinson (1985) have also suggested providing more structured opportunities for students to talk through ideas at length, both in small groups and whole class discussions.
5. These results can be utilized by the teachers in the field of lesson presentation. Frequently these lessons can involve small number of students with little work carried out to trial lesson sequence and their effectiveness in full size classrooms. It is this type of applicable information which teachers need rather than the identification of student conceptions or lesson applications in small group situations. Further, these good lesson plans should model good practice and as such aid in the development of better lesson sequences which attempt to help students to achieve acceptable scientific notions.

6. Models of conceptual change imply that the learners' ability to reforge links between prior knowledge and sensory input is likely to be of critical importance in learning. Teachers' can assist learners by providing the kinds of information and experiences which will enable them to bridge the gaps between sensory input and prior knowledge. Ideas to be taught should always be related to the relevant frameworks held by the learner and revision of the key parts of such frame works should not be undertaken lightly.

7. Explanations of any links between new information and prior knowledge should be made in a variety of ways so that learners are presented with visual, verbal and/or a diagrammatic format of the principles to be taught. Whenever, concepts are to be introduced teachers should provide significant numbers of examples and non-examples. Hopps (1985) also suggested relevant structuring of elementary school science lessons to deal with misconceptions. Generally students study very hard to process information and reach at their ideas. It is not easy to deconstruct these ideas and let go of incorrect ones. Teachers should use a multidisciplinary approach that integrates technology with effective learning and teaching practices to overcome misconceptions. Technology as a part of classroom activities motivates and allows students to learn, communicate, and share their knowledge and understanding in a wide variety of ways. Research studies show that influences of technologies in the science classroom are undoable in a positive way (Saka and Akdenize, 2006) and treatment with technology decrease misconceptions (William and Abraham, 1995).

8. This work has identified new material which can be utilized by science educators both in the classroom and in teachers' pre-and in-service courses. This new material includes a number of misconceptions. These new pieces of information add to the overall picture of students' conceptual development and with this knowledge, educational practitioners will be in a better position to make necessary changes and improvements in their classroom practices to enhance the student learning.
5.3.2 Suggestions for Further Research

The present study was delimited in terms of area of study, course content, and grade level at secondary school stage and to "descriptive method only". Hence the following suggestions may be made for further research:

1. This study was done for assessing the errors and misconceptions of secondary school students about environment. The other concept areas of science learning can be studied and students' errors and misconceptions can be assessed with the help of three-tier test.

2. Similar type of research can be undertaken for assessing the errors and misconceptions in other school subjects as well at different stages of schooling.

3. This research was carried out to assess errors and misconceptions among secondary school students. Similar studies can be done to assess errors and misconceptions among elementary school students and even this type of research can be pursued at graduate/post graduate level in different courses of study.

4. The Concept Achievement Test (CAT) in science was administered to secondary school students taking into account the independent variables i.e. scientific attitude and academic achievement. However, the independent variables such as school type, teacher, intelligence, socio-economic status etc were not taken into account. Therefore further studies should take into account the effects of these variables on the students' misconceptions about environment and other scientific concepts.

5. There is a need to identify the potential pathways that learners may follow while developing conceptions. This approach has the advantage of helping teachers (pre-service and in-service) to prepare material to reduce the incidence of misconceptions formation and can also lead to more information on how learners actually, develop their knowledge. So research can be done which can give the knowledge of the development of specific pathways of conceptual development, the manner in which conceptual growth and development occurs.

6. Another area where future research work could be pursued is in the field of lesson presentations which can be utilized by teachers to overcome identified misconceptions. Further researchers may be conducted to find out effect of various teaching strategies to remove or minimize misconceptions held by students.

7. Research can be made to enhance teachers' awareness of misconceptions and some methods by which these misconceptions can be reduced.