EFFECT OF PAUL-ELDER CRITICAL THINKING MODEL ON THE ACADEMIC ACHIEVEMENT OF SCIENCE STUDENTS AT SECONDARY LEVEL IN BALOCHISTAN

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Submitted in partial fulfillment of the requirements for the

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FORWARDING SHEET

This thesis entitled" EFFECT OF PAUL-ELDER CRITICAL THINKING MODEL ON THE ACADEMIC ACHIEVEMENTOF SCIENCE STUDENTS AT SECONDARY LEVEL IN BALOCHISTAN" submitted by Abdul Majeed in partial fulfilment of the requirement of Ph.D degree in education has been completed under my guidance and supervision. I am satisfied with the quality and originality of student's research work.

Supervisor_____

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Date 22/9/2021

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Approval Sheet

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Chairman _____
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DEDICATION

To my late father whose nature of commitment and determination inspired me ever

&

To my mother, my wife, my son and my daughters, without whom none of this would have been possible

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Abstract

The research study was planned to test the academic achievement of science students at the secondary level in Balochistan through the application of Paul-Elder's critical thinking model in the classrooms and to compare these scores with the academic achievements of students taught through the conventional method. Nine null hypotheses were developed based on the intellectual standards of Paul-Elder's critical thinking model. Clarity, accuracy, precision, relevance, depth, logic, breadth, significance and fairness are nine intellectual standards of this model. All the science students studying the biology of 10th grade in Balochistan were considered as the population of this research study. Besides, the accessible population of this study consisted of two government high schools (boys& girls) in Quetta city. Furthermore, in the design of the research, a type of true experimental design (a pre-test post-test control group) was applied. Teaching methodology and the ability levels of students were used as two independent variables in this study. The teaching method was designed as a collaborative teaching method (experimental group) and conventional teaching method (control group). The ability levels of students have considered as a second independent variable consisted of three levels: higher ability level, average ability level, and low ability level. Due to the use of more than one independent variable, a 2x3 factorial design was designed in this study. In this connection, academic achievement was a dependent variable. For each selected school, 72 students were selected as the sample of the study through a simple random sampling technique. Annual examination scores (AES) of class 9 were used to equalize both groups. Three chapters of the biology textbook for class 10 were used for intervention. The researcher developed 36 lesson plans in the light of intellectual standards of Paul-Elder's critical thinking model for collaborative teaching methods and the same numbers of lesson plans were developed for the conventional teaching method. The researcher developed the students' achievement test (SAT) used for the pre-test as well as the post-test. This test was developed under the instructions of the intellectual standards of this model to assess the critical thinking abilities of students before and after the treatment. This research instrument was validated by expert opinions and by correlating the SAT with the critical thinking test for criterion validity. It was also found reliable through the split-half method in pilot testing. The findings of the study confirmed that Paul-Elder's critical thinking model through the collaborative teaching method has a positive effect with significant differences on the academic achievements of the students (boys &girls) than the conventional teaching method. It was, therefore, concluded that the application of intellectual standards of Paul-Elder's critical thinking model to teach the subject of biology through collaborative method has significantly better results in the academic achievement of students than conventional teaching method. Moreover, critical thinking can be developed in the science students at the secondary level if the teachers apply the intellectual standards in classrooms.

Key words: Critical thinking, Academic achievement, Science students, Secondary level, Factorial Design.

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ABBREVIATIONS

AAs	Average Achievers
AAC	Average Achievers in control group
AAE	Average Achievers in experimental group
AES	Annual Examination Scores
ANOVA	Analysis of Variance
BBISE	Balochistan Board of Intermediate and Secondary Education
CT	Critical Thinking
CTT	Critical Thinking Test
HAs	High Achievers
HAC	High Achievers in control group
HAE	High Achievers in experimental group
LAs	Low Achievers
LAC	Low Achievers in control group
LAE	Low Achievers in experimental group
LEQ	Long Essay Question
MCQs	Multiple Choice Questions
NEP	National Education Policy
SAT	Students Achievement Test
SD	Standard Deviation
SDGs	Sustainable Development Goals
SL	Significance Level
SPSS	Statistical Package for Social Science

Chapter No.1

Introduction

This Introductory chapter consists of eleven sections: study background, critical thinking overview, problem statement, theoretical framework, objectives, hypothesis, significance of the research, delimitation, limitation, study procedure (population, sample, instrument, data collection, data analysis) and definition of the terms. This section introduces the problem under study which is testing the effectiveness of Paul-Elder's critical thinking (CT) model on the academic achievement of science students at the secondary level.

1.1 Background of the study

Quality of our life is related to the quality of our thoughts. Quality education has a key role for human resource development and a necessary element for sustainable socio-economic growth. It is not simply providing instruction to the children but in fact it is the significant social process that serves for mental, physical, ideological, and moral development of young generation to empower them to realize their roles in practical lives. Poverty, aggression, lack of tolerance and deceiving the people in our society is increasing day by day. For the purpose we have to be aware of our thinking process and we can make our life better by critical thinking. Mahmood (2017) explored that from the time of Socrates to the present day; the potential of any individual has a positive effect on education when he or she thinks critically and with rationale. Without critical thinking, students are not able to practice and use information in daily life even receiving degrees. They cannot create new information to make relations between the received knowledge and the practical life, or to develop individual and innovative ideas. According to Wertz (2019), collaborative teaching

method is the teaching strategy in which students interact with teachers and with each other to develop critical thinking. They think, rethink, reorganise their thoughts and develop strategies to solve the problem, for questioning or decision making. Such type of strategies is advocated by teachers that can help students acquire creative thinking and lifelong learning skills. So Dewey (1933) connected critical thinking with education in such a way that the key purpose of education is to develop the ability of thinking.

Khan (2017) concluded her study about the education paradigm in Pakistan. She stated that in the schools of Pakistan, the role of a teacher is as a knowledge dispenser, students are knowledge recorder and memorizer and the role of examination is to test how much students retain and reproduce the knowledge accurately. In addition, the teaching of science in Pakistan has the same paradigm. In the traditional or conventional methods of teaching science, teachers teach a vast amount of knowledge and students collect the given knowledge and reproduce it in the examination. A typical classroom pattern is summarized in fig 1.1

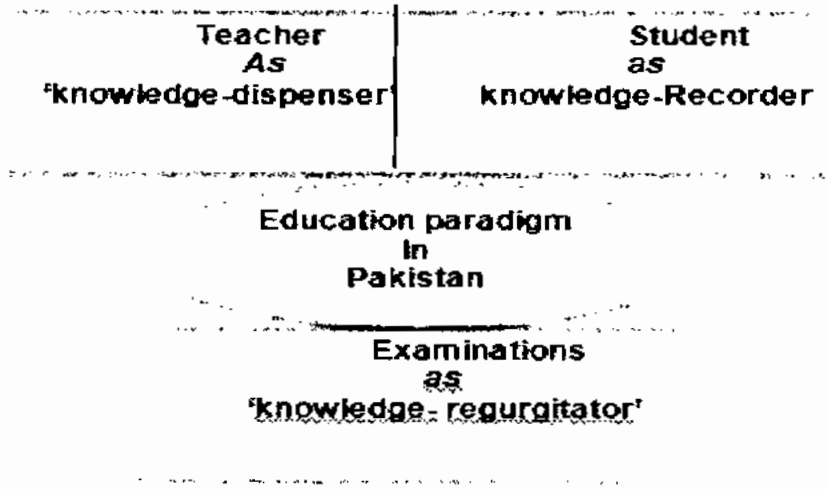

Figure 1.1 Pakistan's Education Paradigm (khan, 2017)

In this context, National Education Policies of Pakistan (2009, 2017) acknowledge the importance of quality education, critical thinking, reducing the dominance of memorization to develop thinking skills and to meet the challenges of the modern world. Critical thinking is considered positive as it benefits the nation, society, community, family, and an individual's life (Paul, 1990). In Pakistan, conventionally, an authoritative attitude of teachers, the threatening classroom environment, textbooks, and learning by cramming are hurdles in conceptual learning (Aly, 2007). This background of study leads to the research question: How do the abilities of critical thinking be developed and assessed in science students at the secondary level in Pakistan?

1.2 Overview of Critical Thinking

According to Annis (2019), some sort of prior understanding of the topic is compulsory for students to think critically. This is to ensure that the process of critical thinking can produce lasting knowledge. Moreover, this topic can help teachers in all subjects because critical thinking is not just useful for students in their learning process but, also for teachers in deciding which teaching approaches to apply. Mahmood (2017) in her dissertation concluded that in European countries, the USA and New Zealand, the concept of critical thinking has deep roots in their societies and education systems. On the other hand, a little awareness of critical thinking is present in the schools, societies, and education systems of India, Pakistan, China, and generally in Asian countries. The idea of "Uncritical Thinking" was proposed by Al-Osaimi, Reid, and Rodrigues (2014) after the concept of absence of critical thinking by Paul (1990). The term Uncritical thinking means never questioning what is taught, which shows the favouritism of teacher or source, material or content, and also

listener or student. They summarized the comparison in diagrammatic form (figure 1.2).

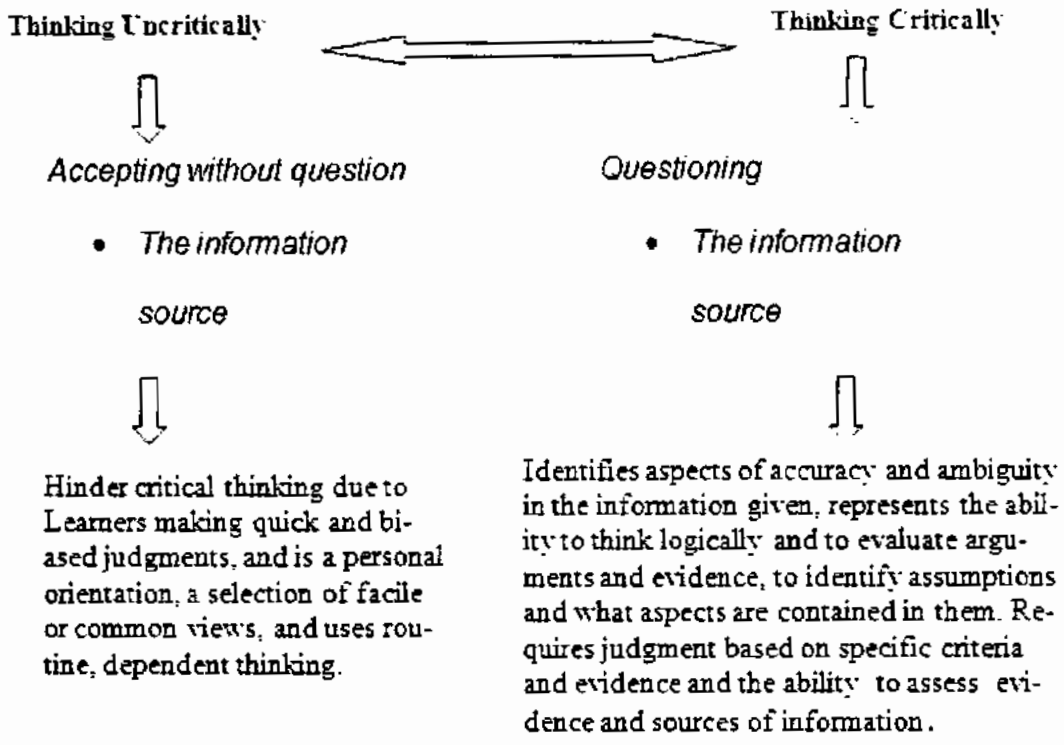

Figure 1.2 Thinking critically and uncritically (Al-Osaimi et al., 2014).

The concept of critical thinking has been summarized into three approaches like the philosophical, psychological, and educational approach by Lai (2011). The philosophical approach highlights critical thinking as a logical process which is ideal thinking. The psychological or cognitive approach highlights the critical thinking of observable things. The educational approach is consisted of elements of both approaches but tends to depend on taxonomies developed originally to guide assessment. According to Ennis (1992), Critical thinking is the disciplined cognitive activity to develop ideas after evaluating the things for decision making. Goodlad (1997) suggested that critical thinking is the need of society. With time, the life skills and global economy need the persons who can well explain their point of view and make well judgments. Moreover, Perkin (1989) identified that we have to look at the

factors which compel on a condition, expect the outcomes of possible practices, assess those outcomes and compare the results with each other, and after evaluation and comparison, choose the positive results. Moreover, the thinking and attitudes we hold depend upon our way of thinking.

1.3 Rationale of the study

In the 21 century, school systems are expected to do more for students than just focus on preparing them for academic tests and improving their test scores. From a holistic point of view, schooling should be helping to equip young people with the tools they need to become engaged thinkers, flexible and resourceful learners, creative problem solvers and active members of their communities. Critical thinking is one of the most important 21 century skills (Lamb, Maire & Doecke, 2017). Giancarlo, Blohm and Urdan (2004) explored critical thinking through assessing secondary students' disposition in California. They indicated four meaningful dimensions: learning orientation, creative problem solving, mental focus, and cognitive integrity. The basic outcome target of Sustainable Development Goals (2015-2030) is to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.

National Education Policies of Pakistan (2009, 2017) acknowledged the importance of quality education, critical thinking, and reducing the dominance of memorization to develop thinking skills and to meet the challenges of the modern world. In the same way, national curriculum, 2006 of biology at secondary level focuses the learning of students through higher-order thinking, deep learning, and reasoning. In this connection, Mahmood (2017) explored the challenges of critical thinking ability in the students of Pakistan. She concluded that without critical thinking students are not able to practice and use information in daily life even

receiving degrees. They cannot create new information to make relations between the received knowledge and the practical life, or to develop innovative ideas. Khan (2017) concluded that course guidelines, role of the teacher, Assessment criteria and background of students in Pakistan are the barrier of critical thinking and suggested that the opportunities should be provided to the students to ask useful and relevant questions and this will require collaboration, where an interactive environment can be developed in the classroom. Moreover, according to the strategic objectives of the Balochistan Education Sector Plan (2013-2018) quality education has been neglected for many years but the strategic objectives of the education sector plan considered it essential as lifelong learning through capacity development of teachers, educational managers, curriculum developers and textbook writers for primary, middle and secondary education (p.34-35). From the above studies, it results a vacuum and big gap in the very important area of critical thinking in the students of Pakistan.

1.4 Statement of Research Problem

The students of Pakistan are not able to practice and apply their knowledge in daily life due to deficiency of critical thinking skill even receiving degrees (Mahmood, 2017 & Khan, 2017). If this trend continues, Pakistani students may not be able to develop innovative ideas and effectively compete in the global economy. To address this issue, this study sought to determine the effect of Paul-Elder's critical thinking model on the academic achievement of science students at secondary level in Balochistan.

1.5 Theoretical Frame work

The theoretical framework is a configuration that offers direction to the researchers by relying on recognized theory. The researchers can use it as a good connection for the constructs of the study (Cresswel, Plano Clark, & Garrett, 2008).

According to the founders of this model, Paul and Elder (2005) critical thinking is a one kind of thinking ability which is applicable in all the academic areas to solve the issues. In this continuity, Paul and Elder (2008) suggested the teaching strategies to improve the critical thinking skills in science students at the secondary level, which structured the basis for the conceptual framework of this study. Introducing the founders of this model, Richard Paul led the movement of critical thinking and worked as research director at the centre for critical thinking in California. Linda Elder is working as an educational psychologist and president of the foundation of critical thinking in California. The focus of their research is to develop critical thinking in education and society (Foundation for critical thinking, 2019). The Paul-Elder model has three components: first the intellectual standards, the second component is the elements of reasoning and the third one is the intellectual traits. Intellectual standards must be applied to the elements of reasoning and the intellectual traits can be developed due to the use of intellectual standards consistently. There are ten intellectual standards in this model that are named: clarity, precision, accuracy, relevance, depth, breadth, logic, significance, fairness and completeness. In this connection, the second component, the elements of reasoning consists of Purpose, Assumption, Point of view which leads to deeper Information, Concepts, questions, Inferences and Implications. So the third component the Intellectual Traits which is classified into Humility, perseverance, autonomy, empathy, fair-mindedness, integrity, courage and confidence.

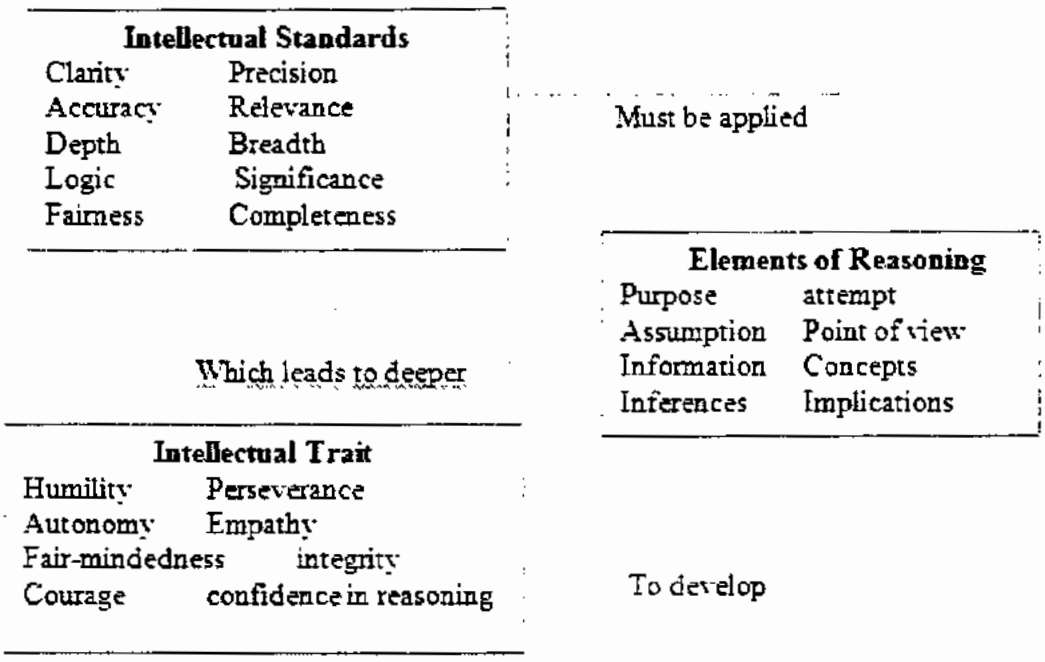

Figure 1.3 Paul-Elder's critical thinking Model (Resource: Paul &Elder, 2008.Foundation for critical thinking.www.criticalthinking.org)

The intellectual standards promote critical thinking in a person when he or she applies to the elements of reasoning to develop the intellectual traits. This model explains all the components, first explaining the elements of reasoning in such a way that when a person thinks, he or she thinks for any "purpose" within a "point of view" and the point of view develops based on "assumptions" which leads to "implications" and "inferences". Moreover, based on inferences, "information" is gained of specific "concepts" to answer the questions for the solution of a problem. Paul and Elder indicate that the intellectual traits define the core of critical thinking. Paul and Elder (2013) suggested nine essential intellectual standards out of ten standards. They suggested that nine essential intellectual standards are significant to expert reasoning in everyday life. Therefore in this study, nine intellectual standards were focussed out of ten, except "completeness". Paul and Elder (2006) believe that within a critical thinking process there are three levels of critical thinking and methodical practice is needed for a person to enhance the levels of critical thinking. First-order and lower

order are *"spontaneous and non-reflective"*, as it contains insight, truth, error, good and bad. For example, if we see a person dressed in torn clothes and who appears untidy. We initially assume he or she is poor and having no hygiene habits may be homeless. On the other hand, a critical thinker assesses and questions the situation, gathers information for the proper conclusion before expressing their views.

The second level or higher order of thinking occurs when first-order thinking is raised to the level of *"conscious action"* in which a person begins to analyze, assess and reconstruct the thought process. Individuals must question their thought process by employing Paul-Elder elements of thought. For example in the completion of this study effectively researcher must identify the purpose or objectives of the study (purpose) decide what questions need to be raised related to the purpose (questions), gather information supporting the questions(inference), come to conclusion based upon the information gathered and identify the main concepts (conclusion) note any assumptions and consequences and interpret from which viewpoint the problem is being resolved or another viewpoint is considered (assumption, consequences, viewpoint). As the elements of thoughts are applied, the intellectual standards follow it by using clarity to identify the purpose, gathering accurate and precise information, deciding the relevance of information related to the questions while including logic and fairness. The highest-order thinking or the third level thinking is developed by the routine use of critical thinking traits and elements which continually analyze and assess thinking. Higher-order thinking result from the mastery of Paul and Elder's intellectual standards and elements of thought and is difficult to achieve unless systematically practiced. Another manner in which Paul and Elder's (2005, 2006, 2013) suggested that this model of critical thinking can be used in the classrooms through different teaching strategies which promote critical thinking skills. They have

identified the effective teaching activities and practices that offer chances for deeper learning which are based upon the use of the critical thinking model. Examples of such teaching strategies that encourage critical thinking skills are briefly described below. Socratic questioning is a questioning approach in which a person can continue to pose questions about a subject, searching for deeper meaning and responses. Another strategy is thinking out loud which benefits others by talking out loud about a topic and hearing multiple responses. Self-assessment and self-reflection are essential to learning as these activities provide the learner with the opportunity to evaluate their thinking which places the responsibilities of learning on the student. Concept mapping makes meaning of a subject matter by building upon previous content and current knowledge by creating a visual map linking themes, patterns, and processes. Science education curricula desire to support teaching strategies for the development of critical thinking skills and improving student's scientific reasoning abilities. The present study, therefore, finds out the effect of Paul-Elder's critical thinking model on the academic achievement of science students at the secondary level.

1.6 Objectives of the study

This research study stipulates a set of the following objectives.

1. To determine the effect of critical thinking on students' academic achievement in biology at the secondary level through collaborative teaching method based on Paul-Elder's critical thinking model.
2. To find out the effect of critical thinking on students' academic achievement in biology at the secondary level through conventional teaching method.
3. To compare the effect of critical thinking on students' academic achievement in biology at the secondary level through collaborative and conventional teaching methods.

1.7 Hypotheses

Based on the objectives of the study, the following ten hypotheses were developed.

H01: There is no significant difference in academic achievement mean score of biology in experimental and control groups based on "Clarity".

H02: There is no significant difference in academic achievement mean score of biology in experimental and control groups based on "Accuracy".

H03: There is no significant difference in academic achievement mean score of biology in experimental and control groups based on "Precision".

H04: There is no significant difference in academic achievement mean score of biology in experimental and control groups based on "Relevance".

H05: There is no significant difference in academic achievement mean score of biology in experimental and control groups based on "Depth".

H06: There is no significant difference in academic achievement mean score of biology in experimental and control groups based on "Breadth".

H07: There is no significant difference in academic achievement mean score of biology in experimental and control groups based on "Logic".

H08: There is no significant difference in academic achievement mean score of biology in experimental and control groups based on "Significance".

H09: There is no significant difference in academic achievement mean score of biology in experimental and control groups based on "Fairness".

H10: There is no significant difference in academic achievement mean score of biology in experimental and control groups based on ability levels of students.

1.8 Significance of Research study

This research study can be significant for the development of curriculum and the writers of textbooks to design activities for the fostering of critical thinking at secondary level students. The results of this study can be shared with teachers and teacher educators during in-service training as well as in the seminars at the national and international level as an applied example of instructions having critical thinking activities for promoting meaningful understanding of science concepts. This study can be helpful to connect the gap between the effective involvement of Critical thinking (CT) in the schools and the improvement of literature. It may enhance the literature about critical thinking on its teaching and learning process through the pre-service and in-service professional development of teachers. This experimental study provides the actual situation of science classrooms that how the students develop the ability of critical thinking in Balochistan (Pakistan) at the secondary level, teacher and student's interaction and communication in the classroom for the valuable learning through the collaborative teaching strategies for quality education of students. This study highlights the concept of critical thinking skills across the discipline to learn and especially to enhance professional practices in science education at the secondary level. In the same fashion, the theoretical foundation to develop the lesson plans of critical thinking and their application may be contributed in this study. This study explains how to adapt the intervention in the classroom for developing critical thinking and quality education. Moreover, Factorial Design research approaches are rare in science education at the secondary level in Pakistan.

The findings of the present research study lead to recommendations for further related studies. The main characteristic of this research study is to develop, apply, and evaluate the instructional intervention in science education. This study can help the

students and teachers to be aware of the teaching-learning process to develop critical thinking abilities at the classroom level in the Pakistani context. This study may also contribute to educational research to validate the literature and research design on critical thinking. The teaching of content on the base of Paul-Elder's critical thinking model may develop the students' abilities to think critically within a discipline and general abilities. Moreover, this model presents the standards to look deeply at the educational curricula for possible consequences. With this intention, this study contributes to investigate the effect of this model to enhance the critical thinking skills in both girls and boys science students at the secondary level.

1.9 Delimitation of the study

This research study was delimited to 10^{th}-grade biology students for three chapters such as Genes and Inheritance, Evolution, and Environmental Biology. Two Government High schools in Quetta City were delimited out of 964 high schools in Balochistan (Balochistan Education statistics 2016-17). Moreover, "intellectual standards" and "Elements of reasoning" the components of Paul-Elder's critical thinking model were delimited for the study. Purpose, hypotheses, literature review, data collection, data analyses and conclusions of this study represent the elements of reasoning. The third component of the model " intellectual traits" was not related to the objectives of this study.

1.10 Procedure of Research study

Following steps were taken by the researcher to conduct the study.

1.10.1 Population of the study.

All the science students at the secondary level in government high schools in Balochistan were considered as the target population of the study. The study was conducted in two government high schools (boys &girls) in Quetta city. So, all the

biology students studying in 10th grade at the selected schools were considered as an accessible population of the study.

1.10.2 Sample of the study.

The present research study has 72 students as a sample from each (boys & girls) selected high school, studying in 10th grade. In such a way, the overall sample of the study was 144 students. The sample of the study was selected through a simple random sampling technique. The researcher divided and equated the sample into experimental and control groups based on pairing the Annual Examination Scores (AES). Class 9th Annual Examination Scores (AES) in biology 2019 were used for this purpose. The paired subjects were allocated randomly to experimental and control groups in both boys' and girls' high schools.

Table 1.1
Sample of the study

Sample from Boys school	Sample from Girls school	overall sample
72	72	144

1.10.3 Research Instrument.

The achievement of 10th-grade students studying biology was measured by applying the student's achievement test (SAT), developed by the researcher. SAT was constructed according to the basic principles of intellectual standards situated in Paul-Elder's critical thinking model. This research instrument was validated by applying construct, content, and criterion validity. Reliability was confirmed through the split-half method.

1.10.4 Data collection and data analysis.

Data of the study were consisted of the scores achieved from the annual examination of class 9, pilot testing, critical thinking test (criterion validity), pre-test, and post-test. Data were analyzed through statistical tests like Pearson's correlation, descriptive statistics, and inferential statistics like dependent sample t-test, independent sample t-test, and one-way ANOVA. The tests were applied by using computer software called statistical package for social sciences (SPSS) V.20.

1.11 Operational definitions

Critical thinking: It is a self-regulatory and purposeful judgment based on understanding, analysis, evaluation, conclusion, and description of the evidence, ideas, and contextual thought (Facione, 1990).

Academic Achievement (Operational definition): Academic achievement is the level or degree to which an institution, students, or teachers can attain their short-term or long-term objectives of education.

Collaborative Teaching Method: Collaborative teaching method is an instruction method in which the learners who learn through collaboration performed better than the students who studied individually (Gokhale, 1995).

Conventional Teaching Method (Operational definition): Conventional teaching method is an instruction method that is used to enhance the knowledge of students. Lecture Method and Demonstration.

Chapter No.2

Literature Review

This chapter includes the review of related literature which helps to conduct the present study, as well as the thorough discussion of Paul-Elder's critical thinking model. Discussion and review begin with the basic conceptual understanding of critical thinking, the concept of different models of critical thinking, Paul-Elder's critical thinking model, critical thinking at the secondary level, critical thinking in biology, instructional strategies for critical thinking, students' academic achievement, and barrier for critical thinking.

2.1 Basic Concepts of Critical Thinking

Umrzokova and Pardaeva (2020) concluded that critical thinking is the ability to know the problem clearly, to gather necessary information, to use the ideas and alternative thinking, to interact with people, to justify and to draw correct conclusion. They also defined in such a way that critical thinking is a necessary condition for freedom of choice, quality of forecasting and responsibility for their own decision. Gurcay, & Ferah (2018) studied on belief of high school science students on critical thinking and self regulation for self efficacy. According to them self-regulation [critical thinking] is a cyclical process whereby learners use the feedback provided externally or self-generated to assess and adjust their learning strategies. Self-regulation provides new ways to analyze information, to interpreted and draw inferences, evaluate situations, and make decisions. When the results of Pearson product moment correlation analysis were examined, it was found that a high level, positive and significant correlation was found between critical thinking and meta-cognitive self-regulation.

DiYanni (2015) stated that Critical thinking can be conceptualized in different ways but it is mainly linked with the ability to question, weighing the arguments, analyzing the quality of evidence, evaluate the decision or claim. Opportunities must be given to the students to ask relevant questions to develop the ability of critical thinking but such opportunities need free of fear and a friendly environment for interaction with each other through group activities and peer discussion. Therefore, it is important for teachers to pay full attention to the content knowledge and teach content to students in such a way that it would not become outdated. Today's critical thinking and lifelong learning skills are the most important skills needed to survive in a knowledgeable and changing society. Teachers need to reflect on current educational practice and adapt themselves to new challenges that will equip students with problem solving, critical thinking, and lifelong learning skills. In formal education, lecture-based instructional strategy has dominated as an instructional strategy for providing information and knowledge over the centuries. This strategy has been used to convey a lot of information and knowledge to large groups in comparatively short time. According to Florea and Hurjui (2015), it is an active learning process for agreeing or disagreeing with information, judging to decide the reality, and altering misinformation to create new information. According to Chaffee (2014) ability of critical thinking is compulsory to evaluate new information. In addition, critical thinking was defined by Dwyer, Hogan, and Stewart (2014) in such a way that it is a meta-cognitive procedure having many abilities like analyzing, evaluating, and summarising the opinions or solutions to solve a problem (Dwyer, Hogan, & Stewart, 2014). Scriven and Paul (1987) states that critical thinking is a cognitive disciplined practice to conceptualize, apply process, analyze, synthesize, and evaluate the knowledge gathered. In the present world, the basic focus is to develop human beings

to acquire the thinking skills increasingly for facing the wonderful changes of the 21st century to decide well and solve societal complicated problems. Among these, the century can be seen as the age of globalization with the rapid change of knowledge and understanding due to the communication and internet. They explained that it is compulsory of skill required to analyze and to evaluate the information for relevancy, validity, and importance. Facione (1990) argued that it is most important to enhance the cognitive skills and questioning habits in students for developing critical thinking.

In the literature (2.1) regarding basic concepts of critical thinking, all researchers highlighted the importance of critical thinking and cognitive development in the education system and curriculum. Most of teachers in the school are unaware about the concept of critical thinking and they need professional development to implement critical thinking skills through modern teaching strategies. They suggested that critical thinking can be developed through debate, questioning, communication, use of technology, rethinking and reorganizing the thoughts to develop the strategies for good questioning and decision making.

2.1.1 Normal thinking and critical thinking.

In the 21st century world of information, many factors are essential for success: interpret complex and ambiguous information; justifiable information from a massive amount of data, make good decisions to solve problems efficiently avoiding negative outcomes. Critical thinkers actively and democratically participate in society. They enter and succeed in the competitive environment and job market and also can work with the people having different society, religion, language, and political party due to interactive and reflective attitude (Franco, Butler, & Halpern, 2015). According to Facione (2015), critical thinking is the instrument of inquiry that can be a powerful resource in education to enhance purposeful and good thinking. The characteristics of

an ideal critical thinker is having correct information, questioning habit, flexible, honest, good decision maker, open and fair, reasonable in selecting the criteria and having consistency of till the result. Brookfield (2012) describes critical thinking differently. He claimed that some people define critical thinking as having negative meaning in such a way that to find faults in others. First of all critical thinking was introduced by Dewey (1910) with the name of reflective thinking in the area of formal education. He wrote a book named "How We Think" and used the term reflective thinking for critical thinking.

According to Paul and Elder (2005), there are main two steps to develop critical thinking: first to identify the strengths and weaknesses of thinking, and second to reshape the thinking in the improved form where necessary. They divided this process into three components. First is the "Elements of thoughts" which is the analysis of thinking due to focussing the parts of the thinking process, second " the intellectual standards" which means the evaluation of thinking that focus the quality of thinking and the third element " Intellectual trait" which means the behaviour that you have learned. Similarly, Paul (2005) defines critical thinking in such a way that it is well organized and self-directed thinking which leads to perfection in a certain area of thinking. He differentiated the concept of both types of thinking that critical thinking is purposeful thinking, unlike normal thinking. Nowadays, educationists named his understanding of reflective thinking as critical thinking. On the other hand, Halpern (1998) suggested that instead of focussing to find faults, the aim of critical thinking should provide meaningful and correct feedback which facilitates to development of the process of thinking. She further explained that finding the faults can be the component of critical thinking that can be used for improvement not for the sake of conviction. In the continuation of the concept of critical thinking, Brookfield (1987)

equates reflective thinking with critical thinking. Lipman (1988) differentiated critical thinking and normal thinking in several ways. According to him, critical thinking is more accurate and precise than normal thinking.

2.1.2 History of Critical thinking

History tells us that critical thinking is not a new concept; it has been about for over 2,500 years. First of all, Socrates acknowledged this concept when he discovered the probing questions because the people were not able to defend their claims logically (Paul, Elder, & Bartell. 1997). Socrates highlighted clarity of thought, intellectual honesty, and living analyzed life. By applying the Socratic Method of questioning, he allowed people to observe the contradiction that often led them to compromise moral and righteous principles. He was recognized that critical thinking can be utilized in different subjects in the education system. First of all, Critical thinking was utilized in formal education system by John Dewey in 1910. He named critical thinking into reflective thinking, which is now a day known as critical thinking Edward Glaser (1941) is the pioneer and father of the modern critical thinking movement. He defined critical thinking by involving three things first the attitude always reflects the experience, second how to probe the questions and reasons, and third to apply these skills of questioning and reasoning. This point of view was related to that of John Dewey. According to him, there is a connection between significant dispositions and learner-centred education. Therefore, teachers and students are connected due to the learning environment where the new information is created and the origin of discoveries due to interaction and thinking not just received from the source. At the end of the 1900s, many persons tried to define critical thinking. Bloom's taxonomy incorporates the cognitive development levels which are present in the hierarchy, consisting of six levels: knowledge, comprehension, application,

analysis, synthesis, and evaluation (Bloom, 1956). In the same fashion, Tama (1989) suggests that critical thinking is the way to give a reason which supports your point of view and philosophy because an unwilling person can be convinced due to reasoning and logic.

Siegel (1989) suggested a concise summary of critical thinking which involves important dispositions or attitudes, secondly, it is a process to make reasoned judgments, and further, he writes that the main focus of critical thinking is reasoning and attitude. Before the work of Harvey Siegel, Michael Scriven and Richard Paul (1987) described critical thinking as an intellectual process of active conceptualization, application, analysis, synthesis, and evaluation of information. A new, interesting, and most important idea about critical thinking was introduced by Bodner (1988) he noted that students often can't apply their attained knowledge outside the context in which they learned. They only knew without the understanding of knowledge. Bodener supported the creation of a new chemistry course that could enable students to make educated decisions on problems of science and technology. By supporting the Bordner, Mathew Lipman (1991) defined critical thinking in four points, first, it helps for judgment, second, it depends on criteria or standards, third, it is self-correcting and the most important is that critical thinking is sensitive to context. It is important to note that Lipman not only stressed a need to evaluate the standards but also the person who thinks critically must be context-sensitive.

Robert Ennis (1996) suggested the definition of critical thinking for beliefs and actions that it is the reasonable decision of a goal about your beliefs and actions. Robert Ennis focused on the practical evaluation of your point of view and action for practical life. In addition to the work of Ennis, Paul, Elder, and Batell (1997) suggested that critical thinking is a cognitive well-planned process of having

application, synthesis, and evaluation the knowledge. According to Halonen (1995) by highlighting the ability involved in critical thinking that involves both physical and mental activity with reflections for justified decision. He additionally acknowledged that critical thinkers do not accept the result blindly rather than ask questions before believing anything to find out the suitable, best, and most reasonable answer, solution. Fung (2005) in her research elaborated the concept of Lipman about the presence of context for critical thinking. She emphasized context as a compulsory condition for critical thinking. Fung believes that within a context the issues or points of view can be easily understandable.

Nosich (2005) focused the reflection, validity, the act of being reasonable, and relies on evaluation principles for critical thinking which shows the real meanings for this term. He thought that reflection should be critical, but reflection alone is not desirable. He defined critical thinking in such a way that it is the stepping back and reflecting for breakdown and reorganizes your thought to develop strategies for effective questioning and reasoning for decision making. According to Willingham (2007), the basic aim of education may develop critical thinkers, and developing the abilities of the student to think critically is very important. Finally, Paul and Elder (2008) stated that critical thinking is the process of your thinking to make your thinking better. In the same way, Elder (2014) recommends that critical thinking is compulsory for good and intelligent decisions in every field of human life. She states that though we naturally reason, we don't always reason well. Moreover, she suggests that human thought is prejudiced, biased, and self-deceived, while individuals are often intellectually arrogant, selfish, narrow-minded, unkind, unpleasant, and hateful. Human thought is often unreasonable and irrational, thus, the need for critical and logical thinking. Humans naturally have the ability of understanding, analyzing,

synthesizing, comparing, contrasting, plan, and evaluating information. Similarly defining critical thinking, Facione (2015) concluded that it is an ability that allows an individual the occasion to raise fundamental questions and problems; gather and evaluate the related knowledge, understand and interpret the information or point of view leading to a logical solution. They added further that critical thinkers always think open-mindedly within alternative areas; and communicate successfully with others.

The literature mentioned in 2.1.2 is summarized in such a way that critical thinking is not a new concept. About 2500 years ago Socrates recognized the need of probing questions and reasoning during a debate. John Dewey (1910) was the pioneer researcher who introduced critical thinking in formal education. Edward Glaser 1941, Bloom 1956, Tama and siegal 1989, introduced modern critical thinking movement and student centred learning. Michael Scriven and Richard Paul (1987) described critical thinking as an intellectual process of active conceptualization, application, analysis, synthesis, and evaluation of information. Bodner (1988), Mathew Lipman (1991) and Fung (2005) defined that critical thinking is sensitive to context. Robert Ennis (1996) Ennis, Paul, Elder, and Batell (1997) suggested that critical thinking is a cognitive well-planned process of having application, synthesis, and evaluation the knowledge. Nosich (2005) focused it as the reflective practice.

2.1.3 Critical thinking as cognitive skill.

In addition to the definition of critical thinking, Edwards (2019) added similar cognitive abilities which are necessary for critical thinking after conclusion of his doctoral study. Critical thinkers develop critical thinking through Socratic Method and should have the ability to identify the main problem in argumentation, be aware of significant relationships with the issue, accurate references from the information and

infer conclusions from the provided information. In this case study high school teachers were asked to implement the Socratic Method in the new academic year to guide instruction and support the development of critical thinking skills in students. It was concluded that study attempted to create a rich and thick description of the perceptions of high school teachers on developing critical thinkers. According to Brookfield (2012) people who think critically not only understand the deep meaning of acquired information but also their thinking and feelings. The people who think critically have the ability to analyze because they interpret out of the way. The reasoning is the key cognitive skill accepted in the literature of critical thinking. He also gives attention to the relationship between critical thinking and judgment in such a way that during critical thinking, people can measure the validity and reliability of their hypotheses or suppositions for the action and associated the term critical thinking for "forecasting possibilities". By the same token, Franco and Almeida (2011) say that critical thinking is the ability to apply higher-order thinking skills in daily life develops a disposition. McGregor (2007) suggested the derived meaning of the word critical thinking. He says that critical is derived from "Kritikos" of the Greek language that means to judge. This derivation shows that critical thinking has a close relationship with judgment. However, Peters (2007) concerns that culture influences reasoning. According to Ornstein and Hunkins (2004), the ability to develop critical thinking skills may be connected to the cognitive-developmental stages of Piaget attached to intellectual potential in daily life experiences. When students have not the ability to reach the formal operations stage their capability to use critical thinking skills is expected to be limited to handle abstract ideas. Egege and Kutieleh (2004) also revealed that it is not compulsory to apply the standards of reasoning for each culture. Lipman (1988) defined critical thinking in terms of judgment. He says that it

guides for good decision making due to having standards, self-assessment, and context-sensitivity. Definition of critical thinking as a cognitive skill was presented by different scholars. However, the excess of ideas of critical thinking can produce confusion. Delphi's report was presented by the American Philosophical Association (APA) to solve this confusion. The report suggests that critical thinking is composed of six cognitive skills: understanding, analyzing, concluding, evaluating, explaining, and self-regulating (Facione, 1990).

Literature related to 2.1.3 revealed that Socratic Method is the key strategy to develop cognition of the students. The people who think critically have the ability to analyze because they interpret out of the way. Critical thinkers validate forecasting possibilities; apply higher-order thinking skills in daily life. Critical thinking skills may be connected to the cognitive-developmental stages of Piaget attached to intellectual potential in daily life experiences.

2.1.4 Critical thinking as affective disposition.

Facione (2015) also suggests that consistent internal motivation creates the disposition of critical thinking. Explaining the intellectual dispositions Paul and Elder (2010) stated that fair-mindedness leads to honesty which can be achieved through seven intellectual traits which are intellectual humility that is resistance to intellectual arrogance, intellectual courage oppose intellectual fearfulness, intellectual empathy oppose intellectual self-centeredness, intellectual integrity is opposing to intellectual hypocrisy, intellectual perseverance is against the intellectual laziness, confidence in reason defend against the mistrust of reason and intellectual autonomy counter the intellectual consistency. Paul and Elder (2005) defined critical thinkers as having strong sense because they have the ability of courage, neutrality, and humbleness to recognize the biasness in the statements of others and even of themselves. On the

other hand, the people who have a weak sense of critical thinking do not agree with others but only defend their own beliefs and statement. By defining critical thinking as an effective disposition, Halpern (1998) discussed that the people who are good critical thinkers identify the specific skill to apply without doing any effort. This shows that cognitive skills have no useful effect without dispositions. In the continuation of defining critical thinking as disposition, Ennis (1996) recommended that disposition is an ability to do anything in a specific condition. Differently, Ennis (1992) says that disposition is the hidden quality. Robert Ennis (1992) pointed out the application of critical thinking. He focused the discussion on the judgment in belief and action. He added that critical thinking helps people with their beliefs and actions to solve the issues. The judgment remained believable if the judge is well informed because he or she can argue before making the decision. He states that a critical individual always asks the right and suitable questions which facilitate clarifying things. Delphi Report (1990) also explained the dispositions of critical thinkers: well informed, probing habit to solve the issue, vigilant to avail chance well in time, self-confidence to give a reason, in the divergent world views remained open-minded and flexible, fair-mindedness to avoid biases, narrow-mindedness, stereotypes, egocentric or socio-centric trends and willingness to change the point of view under the honest reflections.

The best critical thinker is enquiring habitually, knowledgeable, flexible open-minded, trustful of reason, impartial in judgment, combat with personal biases, understanding the problems, having logics to solve complicated problems, having reasons in the selection of criteria, hard-working in quest of related information, focused in questioning and determined for achieving the destination (National Research Council 1997). According to Paul (1990), critical thinkers do not rely on

others and depend on themselves because they are independent learners. According to Siegel (1989) even though cognitive skills and affective dispositions are not similar things, both are commonly supportive and having equal importance. By the same token Siegel (1989) defined disposition that it is the result of the perception of thinking connected with readiness and willingness.

The literature regarding critical thinking and disposition (2.1.4) enlightened that disposition is the behaviour used by someone continuously. Critical thinking is disposition which comes from consistent application of critical thinking skills or intellectual standards. Intrinsic motivation always leads to self regulation. According to Paul-Elder's critical thinking model, consistent use of intellectual standards leads to intellectual traits which is the intellectual disposition. Critical thinking helps people with their beliefs and actions to solve the issues. The best critical thinker is enquiring habitually, knowledgeable, flexible open-minded, trustful of reason, impartial in judgment, combat with personal biases, understanding the problems, having logics to solve complicated problems, having reasons in the selection of criteria, hard-working in quest of related information, focused in questioning and determined for achieving the destination.

2.2 Models of Critical Thinking

Few models of critical thinking were reviewed as under:

John Dewey's model of reflective thinking (1933), indicated critical thinking as reflective as an active process. Any activity based on careful thoughts having reasons. According to him, reflective thinking is the skill to delay the judgement with an open mind. He added that critical thinking is a dynamic process through which the students can think properly by raising the questions for active learning rather than passive learning. Secondly, critical thinking is not just to resolve the issue but also to

reflect the solution of the problem. Bloom's Taxonomy motivates the teachers in their teaching and thinking. Benjamin Bloom (1956) classified human thinking skills into six categories of cognitive domains: knowledge, comprehension, application, analysis, synthesis and evaluation. Knowledge represents the lower level of learning because it consists of rote memorization, second is comprehension which is the lowest level of understanding which refers to classify, estimate, explain, illustrate, predict and summarize the information. Application is the third area in the classification which is a skill to apply the comprehension of information in a new situation. The fourth level of thinking is the analysis which needs skill to compare, contrast, investigate, inferring and examining. The fifth cognitive domain is Synthesis which means collecting the different parts of information to give the shape of new information. It may be discourse analysis or document analysis. Evaluation is the last level of the cognitive domain which is related to the skill to evaluate the information get from synthesis within specific objectives (Bloom, 1956).

Another critical thinking model named Ennis's Model of skill, disposition, and reflective thinking (1987-2011) defines that reflective thinking is actuality critical thinking which guides the next action. He further states that the process of decision-making is critical thinking. According to Ennis (1992) in deciding on doing is helped by one's disposition and abilities. Along with the disposition he suggested the abilities for critical thinkers involving clarification, conclusions, decision making, and integration. Delphi Report (1990) defines the complicated nature of critical thinking: it is purposeful and self-regulatory decision making, based on well interpretation, analysis, evaluation and conclusion. There are seven key features of critical thinking in this report. The Delphi experts were agreed to include the cognitive skill and disposition aspect for critical thinking. It enhances rational autonomy and retards blind

faith, irrational and biased opinions (Facione, 1990). Mathew Lipman (2003) explained the model of applied thinking having contextual aspects along with judgement, standards and self-regulation. He suggested that the result of critical thinking is the evaluation to make a decision, to solve problems and learning new information. In addition, critical thinking relies on criteria. Criteria are the principles or rules used for the making of a decision. Standards or reasons are also the criteria for a good decision. The context of the information remains unique and specific which affects critical thinking. It means critical thinking can't be generalized from one context to another.

Barnett's (1997) model of critical being focused on the extension of disposition: critical being. He argues that critical thinking is contextually dependent. In this connection, critical thinking has three domains. The first domain is knowledge (Propositions, ideas and theories), second: the self which is an internal world that is oneself or self-reflection and third is the world means the external world is the action of critical thoughts. He also explained the disposition of critical thinking which is a capacity to respond differently. Critical thinking is deep-seated. Further, he differentiated the critical person and critical thinker. According to him, critical persons engage critically with knowledge, with themselves as well as with the whole world. So he used the term critical thinking as critical being because it is not limited but also in totality. Paul and Elder's model (2008) focus on the strong sense of critical thinking as well as weak sense. This model is composed of three fundamental components: elements of reasoning, intellectual standards, and intellectual traits. Eight elements are present in the first component Elements of reasoning. These elements are purpose, point of view, assumptions, implication, inference, information, concept and question. They explained the elements of reasoning in such a way that whenever

anyone thinks, any purpose is present behind that thinking and keeps a point of view about that purpose, which is further consisted of assumptions direct to implication and inferences. Furthermore, the information is based on a concept to answer the questions to resolve the issue. The intellectual standards of this model are used to measure the above-mentioned elements of reasoning. There are ten standards in the second component the intellectual standards. These standards are clarity, accuracy, precision, relevance, depth, breadth, logic, significance, completeness, and fairness. According to them, these intellectual standards are used to confirm critical thinking. In this connection, the third component the intellectual traits can be achieved by applying intellectual standards with consistency. These intellectual traits are Intellectual humility, confidence in reasoning, courage, fair-mindedness, intellectual autonomy, persistence, empathy and integrity. These traits are similar to the dispositions presented by other models of critical thinking. Fair-mindedness is the moral motive of this model which is absent in other models. Paul and Elder (2013) suggested nine essential intellectual standards out of ten standards. They postulated that there are nine essential intellectual standards important to skilled reasoning in everyday life. These are the same standards except completeness.

The literature regarding models of critical thinking (2.2) are as under: John Dewey's model of reflective thinking (1933), Benjamin Bloom (1956) classified human thinking skills into six categories of cognitive domains: knowledge, comprehension, application, analysis, synthesis and evaluation. Ennis's Model of skill, disposition, and reflective thinking (1987-2011) defines that reflective thinking is actuality critical thinking which guides the next action. Delphi Report (1990) defines the complicated nature of critical thinking. Mathew Lipman (2003) explained the model of applied thinking having contextual aspects along with judgement, standards

and self-regulation. Barnett's (1997) model of critical being focused on the extension of disposition: critical being. He argues that critical thinking is contextually dependent. Paul and Elder's model (2008) focus on the strong sense of critical thinking as well as weak sense. This model is composed of three fundamental components: elements of reasoning, intellectual standards, and intellectual traits.

2.3 Paul-Elder's Critical Thinking Model

Jun Xu (2012) says that most of the universities in the United States apply this model for the quality of education because this model measures how human beings give reason critically in their statements. According to him, Louisville University, Indiana University, and Montclair state university adopted this model for the Ideas 2 Action Committee, campus writing program, and research academy for university learning respectively. According to Gregory B. Sadler (2010), The Quality Enhancement Plan (QEP) at Fayetteville State University (FSU) has chosen Critical Thinking as its central concept. The Collegiate Learning Assessment Performance Task pedagogical approaches and assessment tool has been adopted as the main strategy for infusing this critical thinking model into the FSU curriculum. Moreover, this model was also be used in this university for the quality education plan. Crenshaw, Hale, and Harper (2011) concluded their research study by using Paul-Elder's critical thinking model that students were better prepared to do the intellectual work necessary for content mastery and self-reflection. Although the extent to which measurable critical thinking skills are cultivated through such engagement over one semester is questionable, initial results (as exemplified by course performance and student feedback) reveal that instruction that focuses on active learning through engaging lectures and the disciplined use of a question generating language helps students develop greater awareness of course content and self. Furthermore, such

approaches are ripe for longitudinal studies so that the question of critical thinking skills can be addressed. What seems to be true, however, is that the development of critical thinking skills is related to the intellectual labour students and instructors put into their work.

Ralston and Bays (2013) concluded that this model for developing assignments and assessing student responses can be duplicated in other disciplines interested in program assessment of critical thinking. Results from the two remaining cohorts will guide further refinement of this engineering school's assessment of students' critical thinking skills. However, these results support that the overt teaching of critical thinking using the Paul-Elder framework has a positive impact on engineering students. According to Karbalaei (2012), Paul and Elder developed a model in 2004 based on the elements of thoughts to analyze critical thinking. This process employs strategic and critical thinking in action. The elements that are used to analyze critical thinking in classroom activities are purpose, question or issue, information, interpretation and inference, concepts, assumptions, implications and consequences, and point of view. Moreover, students need to be given opportunities for consistent, repeated practice of these skills over an extended period. As well, support from the administrative staff along with the implementation of teacher training in critical thinking instructional strategies.

Alfadda, Fatima, Ghaffar, and Afzaal (2020) examined ESL textbooks of the English language of grade 9th and 10th of Punjab model schools in Pakistan. To achieve the goals of the research, the qualitative method was used and applied Paul Elder's Critical Thinking Model (2008) on the textbooks of grades 9 and 10. The collected data was analyzed qualitatively. Activities mentioned in the textbooks of grades 9 and 10 of the Punjab textbook board were extracted and analyzed in the light

of Paul and Elder's CT model. ESL teachers' interviews regarding the said textbooks serve as an insight into the role of critical thinking among learners. In addition, they concluded that the results of the study have significant implications for material developers. The study recommends that the Government of Punjab may provide a training program to the teachers who may get some sort of training and implement on the students the best teaching practices in Pakistan. In the same context, the analysis of interviews shows that teachers have been playing a passive role in the promotion of CT in the teaching process. Hence, there is a need to organize some training sessions to make them aware of the basic concept and importance of CT in Pakistan.

According to literature 2.3 Paul-Elder's critical thinking model is applied in different universities of United States of America. Literature focused the importance of this model. This model can be applied for all the subjects. There is need to organize trainings for teachers to develop their critical thinking skills in Pakistan.

2.4 Critical Thinking at Secondary Level

Coughlin (2010) suggested that students at the secondary level must be aware of the skill of learning, innovation, and use of modern techniques, technology, and media. Teachers must teach the students according to the skill of critical thinking and the students should be responsible for their learning. Students require learning 21-century skills for sustainable learning. For this purpose the students must get, analyze, and evaluate new knowledge, along with this process planning and application of new knowledge is part of critical thinking. Again he added that the real success of students depends upon the use of critical thinking skills than the conventional method in the subject matter. The learning of Critical thinking ability is not restricted in the educational institutions of the world but rational, logical thinking is an important part of life. Critical thinking ability is beneficial to think about any statement, topic,

subject, and issue because thinkers enhance their thinking quality by interpreting, analyzing, evaluating, and reconstructing the knowledge. Moreover, critical thinking abilities cannot be developed automatically in a subject; it is the responsibility of teachers who help the students through taking command, and self-assessment (Paul & Elder, 2008). Similarly, another two researchers Hayes and Devitt (2008) suggested that the abilities of critical thinking are necessary for society. For this purpose critical thinking is a key factor in earning of degree, getting a job, and success of a job. At the secondary level, critical thinking is necessary for the quality education of students in changing environments, learning the content of the subject. Critical thinking engages the methods to understand the deeper meaning of oral or written statements rather than the surface meaning. It differentiates the belief and partiality through applying the intellectual standards of this model (Pescatore, 2007).

2.4.1 Improved academic achievement.

According to Burroughs, Gardner, Lee, Gua, Touitou, Jansen, and Schmidt (2019) academic achievement correlate the teacher effectiveness along multiple dimensions. Teacher effectiveness depends upon teacher experience, teacher education, instructional time, content, and attentiveness to teach. The research was summarized for evaluating the strength of achievement with the teacher efficacy among different countries considering specific dimensions as a separate sample. A significant variation was observed across the countries that confirms about the dimensions of teacher efficacy affect academic achievement. Teacher quality relates to the success of the education system (Burroughs et al, 2019). The finding of the experimental study indicated the importance of project-based learning which significantly improves academic achievements than conventional teaching methods. Moreover, the effect of other related factors for academic achievement was observed

like the area of the subject, location of the subject, duration of teaching, and application of information technology (Chen &Yang, 2019). As indicated by Philip H.Winne and John C. Nesbit (2010) students are in the driver's seat, it is needed to think that how students drive to achieve the goals as academic achievement. By joining meta-cognition and its bigger scope structure, self-regulation learning leads to information and analysis of information. We present the psychology of academic achievement that can progress hypothetically and offer all the more impressive standards of achievement for practice, laws of learning, what the students already know and access throughout learning. How students do self-regulated learning across gathering to adjust in the administration of accomplishing their goals? According to Arbabisarjou Azizollah, Sadegh Zare, Shahrakipour Mahnaz, & Ghoreishinia Gholamreza (2016) motivation is the direct source of achievements and performance of the students. This indicates that students with high academic achievement tend to have better academic performance. Similarly, the motivational aspects motivate the students and facilitate academic achievement and students' cognitive development. The educational system should develop more efforts to encourage education and the related components like the students, teachers and learning environment, and educational facilities. An experimental study by Huppert, Lomask, and Lazarowitz (2010) concluded that learning from the use of computer-like simulation has a significant effect on problem-based learning in 10th class biology students. Therefore, computer-based simulation is the way to improve the academic achievement of the students because the experimental group achieved significantly high scores than the control group in an experimental study.

Coughlin (2010) concluded that the skills of 21 century are the basis of students which directly affect the future of students in the fields of education,

profession, and everyday life. Paul and Elder (2009) suggested that without purposeful involvement and assessment, human believing will, in general, be one-sided, vague, and defective. Nevertheless, this vague and defective information leads us away from a straight path to catch the destination which becomes an obstacle in the quality of our life. Then we use our thinking abilities to solve the problem through the improvement of our reasoning at a higher level. Defective reasoning is then decreased. Unfortunately most students achieve the knowledge from the textbook or lecture that mainly remained out of critical thinking. After passing out the secondary level, the students get knowledge in colleges without proper learning. Moreover, students do not develop the subject learning, or the innate inquisitiveness, to make relations between different subjects. Paul &Elder persuaded that students can differentiate the logic of any subject and think logically within the same subject due to critical thinking skills (Paul &Elder, 2008). Teachers utilizing a CT way to deal with guidance can teach their students constantly to self analyze and validate their thinking and method of reasoning for more achievements. According to York, Gibson and Rankin (2015) academic achievement is the part of academic success. Definitions of academic success vary widely and can be highly subjective. Academic success consists of six components, defining academic success as "academic achievement, satisfaction, acquisition of skills & competencies, persistence, attainment of learning outcomes, and career success. The first component of this model, academic achievement, was constructed on the basis that academic achievement in terms of grades is intended to represent a student's ability to meet criteria for performance.

The literature regarding critical thinking and academic achievement (2.4.1) focused the future of students. Critical thinking is life-long learning instead of surface learning or rote memorization. Competition is increasing day by day in examination

system as well getting jobs in professional life. The solution of this issue is only the practices of critical thinking skills in the learning of content knowledge. Defining academic achievement in such a way that it is highly subjective which represents the student ability to meet criteria for performance.

2.4.2 Improved self and society.

Renatovna & Renatovna (2021) suggested that in order to improve the quality of education in the educational process, it is necessary to create conditions for students, to pay special attention to the study of their interests and needs. Through their learning activities, students' worldviews and thinking are formed, and their conscious attitude to the social system is formed. Similarly, Jensen (2020) concluded the research about performance of society based on critical thinking. Three variables of critical thinking were used. Difference was expected from critical and normal population across all three critical thinking variables of recognize assumptions, evaluate arguments, and draw conclusions. This study showed a difference only existed with the variable of the evaluate arguments. The study expected to learn that the critical thinking profile of performance improvement practitioners was different when compared to the normal population. The research concluded that of the three variables within critical thinking, only the variable of evaluate arguments was different between the two groups studied. The discovery of a difference between the two groups can serve as a starting point to better understand the difference in the evaluate arguments variable. Paul and Elder (2010) recommended that the aim of education does not only make the students employable but also to have a deep perception of the world and understanding the thinking of people around them, in this connection critical thinking is the skill and asset in achieving this point.

Sreejith (2019) suggests learners to engage in a personal struggle to develop a critical consciousness that actively seeks to transform prevailing realities of violence, injustice and un-sustainability toward a culture of nonviolence, justice and sustainability. One helpful pedagogical tool in this process of critical empowerment is to expose learners to inspiring role models of peoples and grassroots communities courageously and patiently building sustainable futures. It is concerned with fostering schools in which students work together to achieve mutual goals, distribute the benefits justly, and develop an identity that unites all students, which can be attained through Experiential learning, Cooperative learning or Participatory learning. Strategies like Role play, Problem-solving, Brainstorming, Journal writing, Exposure trips etc could be judiciously employed (Paul and Elder, 2009). Discussing the development of moral values through critical thinking, Paul and Elder (2009) argued that it is difficult to build moral values in our daily life because we are suffering from egotism, prejudice, self-justification, and self-deception which create problems in human life. In addition, they said that honesty, integrity, self-information, and remained worried for the welfare of others are the bases of moral reasoning. They expected that students get critical thinking skills without being examined and assess their decision from a moral point of view. These students create intellectual aptitudes which empower their abilities to achieve the objectives without wasting the time and how the action and character influence the others in the society. The abilities developed without morals and values are against critical thinking. In the broadest sense, if the objective of teaching is the arrangement of people to encourage them for conscious clarification, then the students must learn abilities of critical thinking along with moral and ethical structure (Pescatore, 2007). According to Pescatore (2007), the learning of abilities in the classroom to think critically remains beneficial for the

students in the future, particularly when students are incited to investigate their decisions ethically. Such a type of thinking skill is a strong instrument for consistency and to avoid being surrender to think about issues from different angles. Pescatore supported the teaching of critical thinking due to its additional advantage of developing commitment in the public instead rather than simply personal responsibility, empowering youngsters to become important powers for change. For social change to happen, people must not just have critical skills about their reading and views.

The literature regarding improved self and society (2.4.1) highlighted the self regulation which is the disposition of critical thinking. The critical thinkers think before decision and become a good decision makers and successful people in society. Aggressive society of Pakistan can be a peaceful society with the use of critical thinking skills.

2.5 Critical Thinking in Biology

Ristanto, Djamahar, Heryanti, & Ichsan (2020) concluded that the cooperative integration reading and composition (CIRC) learning model has proven to be more effective in enhancing critical thinking skills on human excretion and respiratory system. The influence of CIRC learning on critical thinking skills was emphasized on group learning process to discuss and read contents related to human excretion and respiratory system based on scientific approach. According to Quitadamo and Kurtz (2017), the national stakeholders express concern that U.S. college graduates cannot adequately solve problems and think critically. As a set of cognitive abilities, critical thinking skills provide students with tangible academic, personal, and professional benefits that may ultimately address these concerns. Results indicated that the writing group in biology in class 10 significantly improved critical thinking skills whereas

the non-writing group did not. Specifically, analysis and inference skills increased significantly in the writing group but not the non-writing group. Writing students also showed greater gains in evaluation skills. With improved critical thinking skills, general education biology students will be better prepared to solve problems as engaged and productive citizens.

Sungur (2014) concluded experimental research on problem-based learning in high school biological courses. It was concluded that Problem-based learning improved students' use of elaboration strategies, meta-cognitive self-regulation, critical thinking, regulation of their effort, and peer learning when mean scores of the experimental and control group were compared. Besides the reasons previously presented for the interest in CT, specifically in Science Education, science education can and should be a central component in education, dedicated to the promotion of rationality and CT (Siegel, 1989). This author stresses that the power of nations is now not essentially economic, but increasingly related to CT abilities. On this issue, Vieira, Tenreiro-Vieira and Martins (2011) draws attention to the following: In carrying out the scientific activity, which requires the analysis of procedures and scientific results, the application and integration of information, both knowledge, and critical thinking abilities are necessary. These also allow each citizen to understand the work and action of those who have a scientific and/or technical occupation (Vieira and Tenreiro-Vieira, & Martins 2011) and simultaneously, to understand discoveries that constantly allow scientific and technological knowledge to evolve. We live in a world where Science has become an intrinsic part of everyone's life, in which we witness an explosion of scientific information which bombs the world with discoveries every day. In truth, never before has there been as great a need to prepare students to face the dynamic and unpredictable change of outdated scientific and technological

knowledge. These authors added that the use of CT abilities also allows individuals to take a stand on scientific issues, logically rationalizing the issue under discussion, to detect fallacies in arguments, or to suspend the taking of a decision when should there be insufficient evidence to trace and sustain a conclusion. (Gunn, Grigg and Pomahac, 2007). Quitadamo, Faiola, Johnson, and Kurtz (2008) concluded that, while both faculty and students think critical thinking essential, only a small fraction of graduates can demonstrate the thinking skills necessary for academic and professional success. This study compared a research-focused teaching method called community-based inquiry (CBI) with traditional lecture/laboratory in general education biology to discover which method would elicit greater gains in critical thinking. Results showed significant critical-thinking gains in the CBI group but a decrease in a traditional group. Hence, students should learn the Sciences to understand, to assess and to use scientific knowledge. In this context, CT abilities are the key to successful learning (Barak, Ben-Chaim & Zoller, 2007). Additionally, they are necessary for all those who intend to follow careers related to Science. From this perspective, CT may contribute towards a better understanding of Science, to be prepared to act in the context of problem-solving and decision making about the way science and technology are used to change society and vice-versa. Finding appropriate solutions for problems, both within the areas of Biology, of Medicine, or any other scientific/technological area, requires the use of CT abilities for individuals to make decisions, based on the relevance of the reasons found, rejecting partiality and arbitrariness in the assessment of arguments. This is one of the ways of constructing a more realistic image of Science.

Zohar, Weinberger, and Tamir (1994) described the Biology Critical Thinking (BCT) project in which specific critical thinking skills and activities were

incorporated into the biology curriculum. The objectives were to find out whether the BCT project contributes to the development of critical thinking skills in various biological and non-biological topics and how it affects students' biological knowledge and classroom learning environment. Improved critical thinking skills were observed in a new biological context and non-biological everyday topics, suggesting generalization of thinking skills across domains. The experimental students scored significantly higher than the control on a knowledge test, suggesting that "knowledge of facts" is one educational goal and "learning to think" as another, need not conflict, but rather can interact with each other. Finally, the results show that BCT involvement decreased the frequency of teacher-centred teaching and enhanced student-centred, more active learning.

In this review of literature (2.5), different techniques and teaching strategies were discussed to enhance critical thinking skills like cooperative integration reading and composition (CIRC) learning model , Writing and reading skills ,problem based learning, meta-cognitive self-regulation, critical thinking, regulation of their effort, peer learning, use of technology and community based inquiry(CBI).

2.6 Instructional Strategies for Critical Thinking

Hafeez (2021) reviewed on modern learning approaches and review shows that the various new and practical based learning approaches are more effective than the traditional methods of learning. The practical and technology-based learning approaches develop more communication, students learning outcomes and critical thinking than the old and traditional methods of learning. Styers, Zandt, and Hayden (2018) suggested that how students should be facilitated to develop the abilities of critical thinking. The conclusion of this study shows that the debate and discovery learning activities are the high critical thinking activities rather than the lecture and

drill which are low critical thinking activities. They preferred and suggested teaching strategies like questioning for the development of critical thinking skills. Asking questions is also the technique to motivate the students to participate and to critically analyze the material presented and apply, analyze, synthesize, evaluate, assess, and reconstruct knowledge. Even though these courses may be valuable, Santos (2017) concluded the role of critical thinking in science education in such a way that there is relevance and strong relationship between Critical thinking and science education. Nevertheless, problems were found when implementing critical thinking in the science classroom. One of these problems related to the lack of a clarity for applying Critical thinking classroom techniques in science subjects. Though, its nominal (not practical) presence and recognition in science curricula, as well as in curricula in general, is not a problem. There are practical Critical thinking-related strategies that can be applied in science classrooms to improve science education results and critical thinking dispositions on students, one of these is 'questioning', regarded among the most powerful tools.

Modelling critical thinking as a teaching strategy in the classroom is important for student's learning. Teachers require to communicative the thinking processes required for critical thinking, such as identification of the issue, highlighting missing and irrelevant solutions, and evaluate the arguments and results (Ku., Hu, Hau & Lai 2014). With the integration of critical thinking in teaching the content area, some scholars proposed the direct instruction of students in critical thinking. Many universities offer online and distance education courses in critical thinking for different education programs (Ku et al., 2014). Carlson (2012) suggested the effect of instructional methods on critical thinking. This study showed that the instructors preferred Socratic lecture/discussion as the main way of teaching with a strong

association to student perceptions of critical thinking. A moderate correlation to critical thinking was teacher lead discussion, followed closely by brainstorming. While the individual presentations and projects develop the strongest correlation to critical thinking within the classroom. Many Institutes have websites that are used to facilitate the learning activities and teaching strategies to develop critical thinking like Foundation for critical thinking or some universities have centres for teaching and teaching resource centres to provide precious insights and help to develop critical thinking into content courses. Paul and Elder (2010) criticized the teaching strategies to enhance the ability to think critically in the students. They argued that the main reason for the inability of the students to think critically is that how are they being taught. McCollister and Sayler (2010) suggested that the problem-solving teaching-learning process enhances critical thinking in their content area. With this connection, Senechal (2010) suggested a very important point to develop critical thinking. According to him develop the basic skills of learning at the start of education, not its end. Asking questions in learning helps the learner to develop critical thinking and creativity which are higher-order thinking skills. In other words, critical thinking consists of a hierarchy of skills; students should develop first basic thinking skills before reaching the upper critical thought (Senechal, 2010). In the same way, Mendelmen (2007) says that gradual enhancement of critical thinking is the result of the best way of teaching from superficial to complex thinking. According to Beyer (2008), worked on conditional knowledge is an important type of skilled knowledge, it is the skill used under a specific condition. Conditional knowledge is the enhancement of abilities according to a suitable approach. Niedermeyer (2008) supported the conditional knowledge suggested by Beyer and said that self-discovery is the best example of conditional knowledge. In this teaching strategy, students create the ideas

according to their interest and educational background, the teacher remains the facilitator to scaffold the ideas and concepts. Moreover, secondary school teachers are required to establish teaching strategies with critical thinking approaches within their subjects. Bruning, Schraw, Norby & Ronning (2004) suggested that the best way of teaching critical thinking is a sequential way.

Discussing the teaching strategies that are useful for improving critical thinking in the students, Paul and Elder (2005) concluded that teachers have no knowledge of critical thinking or we can say that they have no skill that how to teach critical thinking. Teachers should analyze the reasoning of a piece of writing, essays, or topics to help the students; they applied eight key questions: what are the objectives? What is the main theme of the knowledge? What are the references or sources of knowledge? What are the consequences, the key ideas? What can be the assumptions of the information and main point of view? Paul (2005) states the attitude of the teacher, the perception, and behaviour. Attitudes of teachers sometimes resist the teaching of critical thinking skills. Some teachers feel that students lack the essential background to think critically, have learning disabilities that disallow critical thinking, or they think that critical thinking is time-consuming. Fisher (2001) explains the term critical thinking. According to him, it is a type of thinking having evaluation consisted of criticism and creativity after reasoning and quality of arguments. Anderson and krathwohl (2002) define critical thinking as the ability to act in response, differentiate, make a judgment, infer or conclude to assimilate knowledge. Maiorana (1992) differentiated the active learning and passive learning and proposed that the students' active participation leads to learning, instead of lecture. Dewey (1933) has given the related statement that experience was very important for the student's education for life-long learning.

2.6.1 Collaborative teaching method.

According to Wertz (2019), a large number of institutions face the challenge of the cooperative method, inquiry method, and experiential method because such types of teaching methods facilitate the students to develop critical thinking and creativity. These programs are encouraging and supportive in the training for faculty members. Many teachers may not understand how to facilitate and incorporate planned strategies into their courses that can support this type of enhancement in their students. Cvetkovic and Stanojevic (2017) suggest that teachers can improve the critical-thinking quality of students through learning innovation. Jigsaw and problem-based learning (PBL) teaching strategies can develop critical thinking and innovative ideas. Both types of learning are associated with the collaborative teaching method. The role of the teacher remains facilitator and more interactive (Xhemajli, Cyril, & Methodius, 2016).

Research on the integration of the group-investigation model with the problem-based learning model can develop critical-thinking skills (Asyari, Muhdhar, Susilo & Ibrohim, 2016). Teaching methods like the Inquiry method through asking questions can promote critical thinking in the students. By the same token Chaffee (2014) suggests that this method requires the capability to think critically by evaluating the new knowledge and Facione (1990) argues that the cognitive skills and attitudes are most important to learn for the students. The ability to think critically can be developed through several ways, for example, analyzes the arguments, question the judgments, and evaluate the quality of evidence and claims, which give meaningful thoughts through logical proof that can be developed by asking fruitful questions (DiYanni, 2015). Furthermore, Khan (2017) says that the opportunities should be provided to the students to ask useful and relevant questions and this will require

collaboration, where an interactive environment develops in the classroom (Khan, 2017). In this connection problem-based learning (PBL) is the best way to collaborate with others, in which the teacher assigns the problem to the students and the students search for information from different sources to solve the problem. They interpreted, analyzed, and infer to decide the most suitable solution to solve the problem. The teacher evaluates the students' works (Eggen & Kauchak, 2012; Alrahlah, 2016).

Critical thinking can be developed through presenting the problem because the students are required to resolve the problem. Any procedure which is required to solve the issue needs thinking activities to analyze, evaluate, and create the new information (Asyari, Al Muhdhar, Susilo, & Ibrohim, 2016). Another teaching strategy to develop critical thinking is "Discussion" during the process of learning. (Schoenberger-Orgad & Spiller, 2014).The cooperative learning model can be applied during the learning process because this model provides a chance for students to discuss with each other, cooperate, and invite each other to discuss a subject matter. The reviews of the research on the effectiveness of critical thinking, collaborative teaching methods have a key role to develop critical thinking skills (Abrami, Bernard, Borokhovski, Waddington, Wade, Persson, T. 2008, & Lai, 2011). Presenting the videos of science, mathematics, and philosophical ideas through multimedia, brainstorming, drawing, graphs and pictures or the written work on paper or a screen make connections of thoughts and actions to make cognition clear and deep (Chin, Dohmen and Schwartz, 2013). The teaching method of active learning fills the gap between critical thinking theories and practices and provides a paradigm change from passive to active learning because teachers can teach the passive students providing the active learning environment (McFarlane, 2015; Piergiovanni, 2014). In addition, active learning can be practiced in different ways, many have discussed the use of case studies to develop

the abilities of critical thinking and resolving the issues in undergraduate (Behar-Horenstein & Niu, 2011; McFarlane, 2015).

Slavin (2011) found that the cooperative method is a teaching strategy for the learning of students in small groups and the students enhance their learning based on reward or punishment which he named individual accountability. Students should be assigned sub-tasks in small groups with rewards or personal accountability. This type of action shows a positive effect on the learning of students. It can also be useful in large classes, some science teachers plan strategies to keep the students busy through questioning and to solve the problem. These are the ways or techniques to facilitate the students to be active participants from the passive listeners. It was concluded by the researcher that cooperative learning was started slowly due to the lack of experience of students in group work and it should be started at the start of the session rather than the midterm. According to Ainsworth (2006) peers collaboration cover-up the act of coordination, consultation, communication, and cooperation that may potentially attain positive results than individual work. Teachers can utilize group discussions and Peer work techniques in the classroom to develop critical thinking. With this connection, Johnsen (2009) concluded to show the effect of group work on the behaviour of students. He explained that when the students have involved in different types of group formation the behaviour of students refined because they learn how well they work together. Moreover, in group formation maybe was no real change in the achievements of students, but the longer the group worked together, they perform better. Furthermore, simulation is another teaching method to develop critical thinking. Abdullah and Shariff (2008) assessed and concluded their study to show the effect of inquiry-based computer simulation. According to them, inquiry-based computer simulation enhances the understanding of concepts and scientific

reasoning such as the gas law in a science classroom of students. Short video clips followed by directed discussion are also the teaching strategy to enhance the abilities of critical thinking. Moreover, they suggested the Socratic questioning for the enhancement of abilities of critical thinking. In the same fashion, Paul and Elder (2008) categorized the Socratic questioning into three types which are spontaneous questions, exploratory questions, and focused questions. According to the context, all these methods of questioning are useful to enhance critical thinking abilities. Spontaneous Socratic discussion can be demonstrated beneficial particularly when students take interest in any topic or when they raise a significant issue during learning. Even though there is no already plan that exists for spontaneous discussion. It is the technique to probe the follow-up questions. In exploratory Socratic inquiries, teachers can utilize exploratory Socratic addressing to find issues of interest or debate or to discover where and how students have coordinated content material into their thoughts and attitudes. This type of inquiry can help to determine what students have achieved from their content knowledge for future assignments. In Socratic Focused discussion, teachers focus on particular topics, particular issues, and particular content. Anytime in that educational plan, one may utilize focused Socratic discussion. Here are some possibilities: probing the problem. clarity, depth, analyze and evaluate the thoughts to create new knowledge. This type of questioning technique motivates the learners to think from different angles and also have the ability to communicate their point of view or statements (Paul and Elder, 2008). Roth (2010) observed and concluded that the true understanding depends upon the specific culture and values. Teachers should plan different teaching strategies having values within a culture help the students to enhance the ability to learn otherwise discard to learn.

Kogut (1996) established strategies for teachers to encourage critical thinking skills for the students. These skills are to ask questions regularly and direct them to individual students. The nature of questions should be why and how not simply yes or no type questions. Moreover, the examples and diagrams challenge dualistic thinking and strengthen the idea that science does not have many correct answers. In addition, encourage discussion in group assignments among the students. Along with discussion teachers should give effective feedback and encourage critical thinking. He concluded that in addition to enhancing student critical thinking skills, these strategies can enhance the performance of examination, and encouraged students to become more active learners. Slavin (1995) argued that in many countries and all types of schools, the cooperative learning technique enhances the academic achievement of the students. Mastery learning can also be produced in the students through individual assignments, personal and group work accountability, and teacher feedback to students as critical mechanisms. According to Johnson and Johnson (1989), the collaborative teaching method is such type of teaching method in which the learners learn in small groups which were already planned to get the common goal. The effect of cooperative learning is suggested by Slavin (1988) in such a way that cooperative learning strategies are not only effective in academic achievement, but also effected positively in self-esteem, intergroup relations, and the ability to play with others.

In addition, Gokhale (1995) proved his hypothesis that the students in collaborative learning perform better significantly than the students learning individually. Think pair and share project method is the cooperative learning technique suggested by Biggs (1996). According to him, such types of strategies can develop the learning experiences in their study. Committee on Undergraduate Science Education (1997) set the criteria to teach the students in the classroom. First of all,

keep in mind that there should be no rote memorization of knowledge from the textbook but also other relevant resources can be used for learning. The teacher should use different types of games like puzzles, current events, or examples from everyday life to engage the students. The teacher must start the class with the information which should be interesting, important, and familiar to the learners. The teacher should revise the main points at the end of the class. Another technique is time management which is most important to adjust and to complete the topic within a limited time according to the cognitive level of students. The body language of the teacher has positive effects on the learning of students. Therefore maintaining the eye contact of a teacher with all the students in the classroom is the best interactive tool. The teacher should move around the classroom according to the need. Interact with students even using the whiteboard. The teacher should avoid standing in front of the board or screen.

Review of literature related to 2.6.1 regarding cooperative learning , it is pointed out different strategies of cooperative learning enhance critical thinking in students: practical and technology-based learning, debate and discovery learning activities, Socratic lecture/discussion as the main way of teaching with a strong association to student perceptions of critical thinking, brainstorming, problem-solving teaching-learning process enhances critical thinking in their content area, In other words, critical thinking consists of a hierarchy of skills; students should develop first basic thinking skills before reaching the upper critical thought, gradual enhancement of critical thinking is the result of the best way of teaching from superficial to complex thinking, active and cooperative learning like group discussion and think pair share.

2.6.2 Conventional teaching method.

Wulandari and Kartowagiran, (2020), concluded by comparing the inquiry based learning and conventional learning in science students of high school that the learners remained passive learners in conventional classes and explained the conventional teaching method in such a way that, mainly teachers deliver lectures and students remained active cognitively but inactive physically. Students listen more to the teacher's explanation in front of the class and carry out assignments if the teacher gives exercises to students. This shows that the teacher's dominance in the teaching-learning process is very large while students are passive and only carry out activities through the teacher's deeds. Usually the students remained busy taking the notes. Weber and Johnson (2011) say that the human brain can't think normally in the conventional teaching method because students remained busy in rote memorization and the students were assessed on the reproduction of the content. The role of the teacher is dominant where aggressiveness and physical punishment is part of this dominancy. So in this environment students feel uneasy and the interest of the students cannot be maintained. A personal experience of the concept of conventional teaching method by Mazur (2009) was shared and argued that, in the traditional classroom, teachers transferred instructions to students and students noted the instructions in their notebooks. Teaching was more than transferring instruction from teacher to student. For connecting new information to previous knowledge, Mazur suggested that students should read the topic before coming to the classroom for better results. In addition, he suggested that how to convert a traditional classroom into an interactive class. In the classroom, a teacher needed to deliver a mini-lecture and provide a short period of two minutes for small group discussion. In evaluating the knowledge of students after discussion, a teacher needed to ask questions. Mazur

reported that this technique was helpful for students because it shifted the focus from the teacher to students. Moreover, this technique promoted the student critical thinking by engaging them but the large class of students cannot interact with each other and very little learning can be contributed.

According to McIntosh (1996), teachers believe in the reward and punishment theory of learning. Physical punishment creates a threat in the students and the grades can be the reward in a conventional teaching method. The learning environment of the classroom depends upon command and obeys rules which usually can't say or discuss any issue in the classrooms. There is no chance of questioning, debating, or applying the acquired knowledge due to one-way communication. Students remain passive in the classroom and the teacher is active and a source of knowledge who writes the main points of the topic on the white/blackboard and students take its notes. The focus of the teachers is to cover the syllabus within a limited time; therefore mostly teachers have no time to discuss the issues or difficulties in deep learning of the topic. Caine and Caine (1995) suggested that it is the ground reality that teachers teach the students through conventional teaching methods in our schools. The famous form of this method is the lecture method. Teachers teach different subjects to the students through this method regularly in almost all levels of education. The conventional teaching method is teacher dominant approach because the teacher transfers information authoritatively. The conventional teaching method mainly focuses on the listening ability of the learners present in the classroom. The listening skill helps the students with rote memorization. Such type of teaching develops the surface knowledge, a replica of the taught content. The students were assessed mainly on the word-to-word recovery of knowledge given in the textbooks only. In the same way, Munson, (1992) suggested that in a conventional teaching method there is no interaction between

students and teachers. It has been observed and concluded that students remained silent and passive in their classrooms but only the voice of the teacher is being heard during the session (Munson, 1992). According to Vella (1992) formal or oral presentation of subject material occurs in the traditional teaching strategies. The demonstration is also a teaching strategy of conventional teaching method which can be very fruitful to illustrate the concepts in class but is passive learning because the teacher is active and students just observe without concentration to attract the students. Teachers can motivate the students to think about the illustration having surprise and challenge. In demonstration strategy teachers have little preparation by using everyday objects can be effective for the students (Shakhashiri, 1992).

Review of literature related to conventional teaching method (2.6.2) shows that traditional classroom, teachers remained active and students remained passive and listen the teacher and noted the instructions in their notebooks. Critical thinking can be developed in traditional class rooms if a teacher deliver a mini-lecture and provide a short period of two minutes for small group discussion. In evaluating the knowledge of students after discussion, a teacher needed to ask questions. This technique can be helpful for students because it shifted the focus from the teacher to students.

2.7 Barriers to Critical Thinking

Khalid, Bucheerei and Issah (2021) concluded that students' background, the teaching methods employed in class, the classroom structure, and the available resources that do not foster critical thinking as main barriers to the implementation of critical thinking in the classrooms of Bahrain. Teachers need additional knowledge and skills on the implementation of critical thinking in the classroom. The use of teaching methods such as lecturing and large class sizes, and available resources are

obstacles to the promotion of critical thinking skills in the classroom. According to Crockett (2019), teachers can explore concepts that help the students think more critically by using real-world examples. However, teachers must be familiar with the barriers and issues to teach critical thinking skills. Most essentially, we must learn how to overcome these barriers. The most common barrier to critical thinking is egocentric thoughts which are thinking about everything concerning oneself. Such type of thinking gives direction to the inability to analyze and evaluate various aspects and have no flaws within themselves. So egocentric is the barrier to developing critical thinking skills, whenever teachers will not have flexibility in egocentrism, it will be impossible to facilitate the students for the enhancement of critical thinking in the classroom. Especially during social conflicts, teachers can help the students not to point out the views and attitudes of others. Thinking in the group can lead to harmful decision-making example. Like egocentric thinking, it is difficult to overcome. Teachers should play a key role to encourage independent thoughts and action in students.

According to Crockett (2019) stereotyping is the factor that guides social conditioning. It blinds the eyes of thoughts from the real situation and we make our assumptions within the boundaries of stereotype. Most of the students do not understand these boundaries because they do not think out of the spectrum. There is a main role of teachers to facilitate their students how to assess their thinking. It is necessary to teach intellectual standards like clarity, accuracy, and fair-mindedness in their thinking process. Moreover, he introduced another barrier which is Personal biases that can prohibit critical thinking because they prevent the thinker from being fair, questioning, and open-minded. This type of thought stops people to use their reasoning, common sense, and also experiences to make decisions. According to him,

teachers should motivate the students to be logical for critical thinking. This can be occurred due to the clarity, accuracy, and evaluation of their thinking. Another barrier is the time constraints to integrate the learning opportunity for critical thinking because teachers' responsibility is to complete the syllabus within the limited period. True critical thinkers have no sign of arrogance and intolerance in their minds. Arrogance and intolerance produce close-mindedness which can be the big barrier to solve the problem and good decision making because it blocks creativity.

According to Middendorf and Shopkoh (2018), teachers want their students to do better work but do not know how to get them to do better work without giving them the answer. Teachers are aware that they want to teach the students more than a bunch of content, but they are not really sure what the more is, although they know it when they see it in their own work and in the work of others. As indicated by AliAkbari and Sadeghdaghighi for a little scope (just 100 teachers) from Iran in 2013. The study separated the information into eight sub-scales comprising of students' qualities, self-effectiveness, lack of knowledge, staff obstruction, content included, significance, and importance of basic reasoning, institutional barriers, and time requirements. Over half of the teachers respond that they have not proper pre-service training or continuous professional development to teach critical thinking (Aliakbari and Sadeghdaghighi, 2013, p. 4). Barriers related to students are selecting the correct answer and fearing being wrong. Moreover, students' barriers are an absence of enthusiasm for the subject; an absence of enthusiasm for critical thinking basically and the absence of involvement with improving basic reasoning aptitudes (Aliakbari and Sadeghdaghighi, 2013; Carlson, 2012).

Dewey (1910) suggests that critical thinking barriers are categorized into two types named intrinsic and extrinsic. One of the intrinsic is temperament and the

extrinsic proceeds from generic social conditions. Ozkan-Akan (2003) directed a survey study and included 522 educators in four different areas of Turkey. She collected general views of educators on basic reasoning, teacher barriers, students' obstructions, barriers of curriculum, and outside variables. Her discoveries indicated educators' apparent serious issues with the need to cover the syllabus (82.1%), the need to use lecture (75.5%), and lacking time to utilize critical thinking in the classroom (70.7%) (Ozkan-Akan, 2003, p. 46). Just 80.3% of these respondents felt that students feared being incorrect in their answers, while 89.4% accepted that students favor exercises and assignments with straightforward, genuine inquiries and answers (p. 47). Approximately three-fourths (74.2%) of the educators felt that students were not ready to take part in critical thinking exercises while 78% felt that students have no prior knowledge or knowledge of the world used for critical thinking (p. 47).

Dewey expresses that our assumptions, both intrinsic and extrinsic, influence the mode of thinking. These thoughts slow down one's capacity to think critically (Dewey, 1910). John Locke gave his understanding into critical thinking when he presented four classes of men and why they think in which they do. The first is the individuals who only occasionally reason by any means, however, think as indicated by the case of others, in this way they spare themselves of reasoning; Secondly is the person who thinks with enthusiasm rather than reason, turning to whatever suits his/her interest; Third is the individuals who promptly follow reason in a real sense, but this reasoning inherent to the interest and limited knowledge; Finally, there are the individuals who reason as a result of power, that is, they won't reason outside the comfort of their friends, neighbourhood, or nation (Locke as referred to in Dewey,

1910, p. 23). Every one of these four hurdles of thinking and, even today, places barriers on the basic reasoning procedure.

Review of literature (2.7) regarding barriers of critical thinking, there are following main barriers of critical thinking development in the students. The teaching methods employed in class, the classroom structure, and the available resources that do not foster critical thinking. Egocentric thoughts which are thinking about everything concerning oneself without doing self assessment, stereotyping is the factor that guides social conditioning. It blinds the eyes of thoughts from the real situation and we make our assumptions within the boundaries of stereotype, most of the students do not understand these boundaries because they do not think out of the spectrum, Personal biases that can prohibit critical thinking because they prevent the thinker from being fair, questioning, and open-minded, True critical thinkers have no sign of arrogance and intolerance in their minds, bound of syllabus, absence of enthusiasm for the subject; an absence of enthusiasm for critical thinking basically and the absence of involvement with improving basic reasoning aptitudes, lack of intrinsic and extrinsic motivation.

2.8 Summary of Literature Review

Stakeholders in science education at the secondary level in the world address the problem of critical thinking to enhance academic achievement. They are searching and implementing the curricula, theories, and models to solve the problem, while many studies have been conducted to solve the issue of lack of critical thinking. The critical thinking concept by Florea & Hurjui, (2015) indicates that critical thinking is an active learning process for agreeing or disagreeing with information, judging to decide the reality, and altering misinformation to create new information. Normal thinking and critical thinking were differentiated by Lipman (1988) and other

researchers. The history of critical thinking was mentioned in this chapter which focused from Socrates thoughts to Dewey (1910), Edward Glaser (1941), John Dewey (1933, (Bloom, 1956, Carrol Tama (1989), Scriven & Richard Paul (1987), Bodner (1988), Lipman (1991), Robert Ennis (1996), Daniel Fasko (2003), Yuen Yee Fung (2005), Linda Elder (2014). Critical thinking as a cognitive skill as well as cognitive disposition was mentioned in such a way that cognitive skill is the ability to involve the following cognitive abilities like to interpret, analyze, infer, evaluate, explain and self-regulate (Facione, 1990). Some models of critical thinking are suggested by the researchers like Dewi (2004), Benjamin Bloom (1956), Delphi Report (1990), Lipman (2003), Barnett's (1997), and Paul Elder (2008).

Justification of Paul-Elder critical thinking Model was reviewed in such a way that several universities are applying this model to facilitate the students in learning and developing critical thinking at secondary level for the self and society (Paul & Elder, 2008), Sreejith (2019), Pescatore,(2007). Instructional strategies for critical thinking show that asking questions (paul-elder,2003), active participation of the students(Maiorana,1992), the attitude of teacher affect the critical thinking (Paul, 1995), Socratic lecture/discussion as the main way of teaching with a strong association to student perceptions of critical thinking (Carlson, 2013), the problem-solving teaching-learning process enhance critical thinking in their content area (McCollister and Sayler, 2010). Barriers to developing critical thinking were reviewed. According to Lee Watanabe Crockett (2019) egocentric thinking, stereotyping and personal biases are the main barriers to think critically. Dewey (1910) suggests that the barriers are classified into two types which are intrinsic and extrinsic. Ozkan-Akan (2003) indicated the lack of time in the classroom as a barrier to develop critical thinking.

Chapter No.3

Methodology of the Research

This research study was conducted to find out the effect of Paul-Elder's critical thinking model on the science students' academic achievement at the secondary level. The academic achievement of science students after eight weeks of intervention in the experimental and control group was compared to evaluate the effect of the model. Three chapters (17, 18 & 19) from the class 10^{th} textbook of biology 2019 were selected for the study, Genes and inheritance, evolution, and environmental biology are the names of these chapters respectively. Lesson plans were developed based on collaborative teaching method and conventional teaching method for the experimental and control group respectively. Lesson plans were validated with the help of biology teachers and the opinions of the experts. The researcher developed the students' achievement test (SAT) as the research instrument to collect data on academic achievement of the students. This instrument was constructed by the researcher by using the nine intellectual standards of Paul-Elder's critical thinking model. This chapter is comprised of research design, the population of the study, sample and sampling, research instrument, data collection, and data analysis.

3.1 Research Design

For the conduction of this experimental study pre-test post-test control group design, a type of true experimental design was selected. For the four groups (male and female), this design is denoted as follow:

R	O	X1	O
R	O	X2	O
R	O	X3	O
R	O	X4	O

Symbol " R" refers to the fact that all the subjects are randomly selected, "O" indicates Pre-test as well as post-test, X1 and X3, represent the treatment of male and female experimental group respectively, whereas X2 and X4 represent the treatments of control groups (male and female) respectively. A factorial design was used to test the effectiveness of Paul-Elder's Critical thinking model for particular levels (Higher achievers, Average achievers, and Lower achievers).

Table 3.1
2x3 Factorial analysis of six groups

		Factor B **Academic Achievement**		
		High Achievers (HAs)	Average Achievers (AAs)	Low Achievers (LAs)
Factor A **Teaching Method**	collaborative	**Group1** Mean result of Academic Achievement	**Group3** Mean result of Academic Achievement	**Group5** Mean result of Academic Achievement
	conventional	**Group2** Mean result of Academic Achievement	**Group4** Mean result of Academic Achievement	**Group6** Mean result of Academic Achievement

When your research study has more than one variable then the factorial design is applied and the variables are called factors. In this study, factorial design has two factors including instructional method (collaborative method, conventional method) and ability of students (high, average, and low), named as 2x3 factorial design where the instructional method was designed as a manipulated factor. Collaborative method and Conventional method, High ability, average ability, and Low ability students were considered as the levels of these two factors. Collaborative and conventional classes were equally subdivided into high ability, average, and low ability students based on their marks achieved in the grade 9th annual examination. A factorial design was applied to both male and female subjects (Gay, Mills, & Airasian, 2012).

3.2 Population

The population has been defined by Gay, Mills, and Airasian in such a way that it is the target group which is the group of interest of the researcher and the result of the research study can be generalized. Population by its characteristics needs to be accessible or available in terms of time and cost. Thus the population is a realistic choice, not an idealistic one (Gay, et al, 2012). In this study, the target population has consisted of all the science students at the secondary level in Balochistan. It was not possible to reach the target population. Therefore the researcher defined the accessible population of this study. In this connection the 10th class biology students in Government High School (Boys) satellite town, Quetta, and Government High School (girls) satellite town, Quetta were considered as accessible population. These schools were selected due to the availability of the following factors:

i. The availability of minimum 30 students in each group for experimental study (Gay, et al, 2012 p.139).

ii. Presence of favourable learning environment.

iii. Willingness and enthusiasm of management to teach the particular students for two months.

iv. Travelling from one school (boys') to other (girls') was manageable to teach the classes on daily basis.

Table 3.2
Accessible Population of the study

School type	Biology students (Class 10th)
Boys	123
Girls	139
Total	262

3.3 Sample and Sampling of the Study

A sample is a small group of individuals, things, or events representing the characteristics of the large group from which the sample is drawn (Gay, et al, 2012). The researcher initially selected 80 subjects from each accessible population of boys (123) and girls (139) students through a simple random sampling technique. In addition, the researcher recorded the Annual Examination Scores (AES) in the biology of class 9 from the official record of concerned schools, held in February 2019 under the Balochistan board of intermediate and secondary education (BBISE). (Appendix 5&6). The researcher divided and equated the sample into experimental and control groups based on pairing the Annual Examination Scores (AES). The scores of the students have ranked accordingly and the matching pair was formed according to the marks. Experimental and control groups were allocated to the matched pair students through simple random sampling. Eight students were excluded from each sample (male &female) that was not matched in pairs. Therefore each experimental and control group has 36 students as a sample.

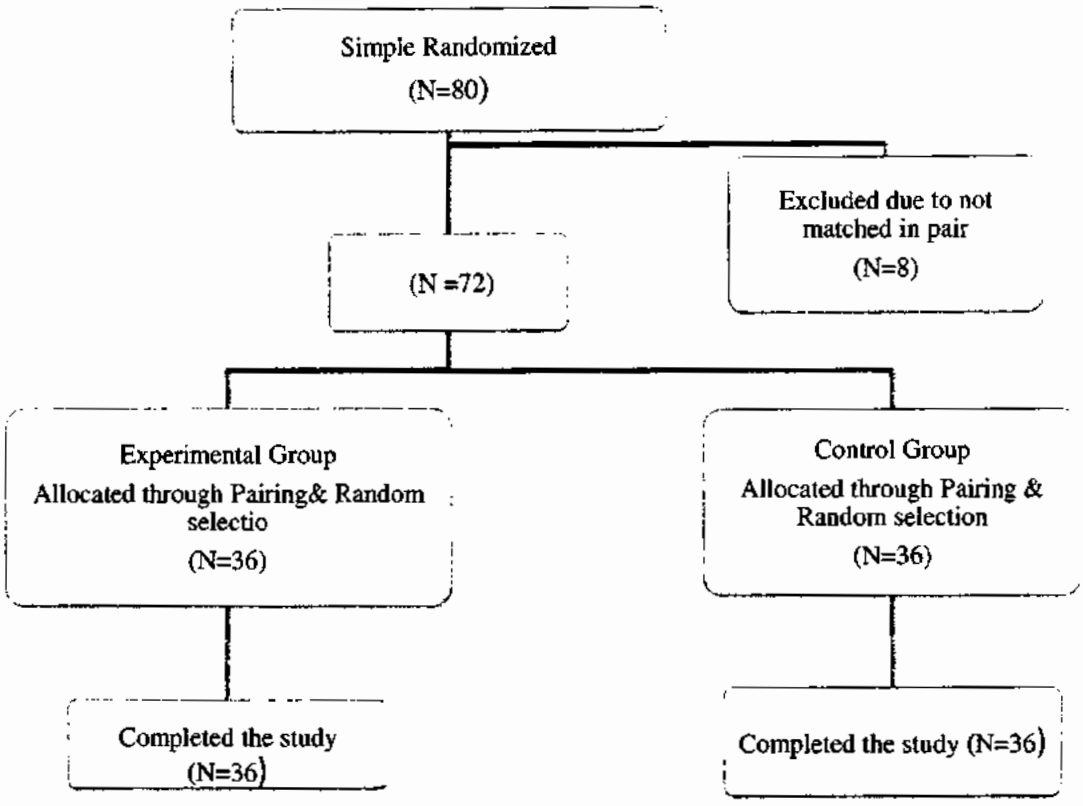

Fig 3.1 Sample and sampling of the study

Thirty six students in each group were distributed in to ability level groups like High, average and low achievers represented as HAs, AAs, and LAs respectively. Selected 12 HAs were numbered from 1-12 where as average students were numbered from 13-24 and the low achievers ranges from 25-36. These students were placed in these categories according to the list of scores taken from AES of class 9th. Ability level groups in each secondary school were distributed as follow:

Table 3.3
Formation of ability level groups from experimental and control groups

	Levels of Achievement	**Group I Experimental** Numbering of the students in the specified list	Total No. of Students Included in the Sample	**Group II Control** Numbering of the students in the specified list	Total No. of Students Included in the Sample
1	**HAs**	1-12	**12**	1-12	**12**
2	**AAs**	13-24	**12**	13-24	**12**
3	**LAs**	25-36	**12**	25-36	**12**

3.4 Selection of Text

Before the selection of text to conduct experiment, researcher considered the specific text on the following basis.

i. Meeting to discuss the syllabus covered by the working teachers of concerned 10th classes

ii. Course out line of 10^{th} grade biology proposed by Balochistan Board of Intermediate and Secondary Education, Balochistan.

iii. School examination limitations. Three units of class 10^{th} biology were planned for intervention. Biology text book, published from Balochistan Text Book Board Quetta, 2018 was used for the purpose.

The detail of these three units is as follow:

Chapter 17 "Genes and Inheritance" contains the following sub topics. Heredity, genes and their role in biological inheritance, crossing over and its significance, DNA, the genetic material, how do genes function?, Patterns of inheritance, Mendel's law and we the human, sex determination and sex linkage in man, Pattern of sex linked inheritance and y linked inheritance and genetic

engineering. Chapter 18 "Evolution" is consisted of three sub topics, which are "Variation", "Theories of evolution" and "Evidence of evolution". Subtopics of chapter 19 "Environmental Biology" are the parts of environment, environmental interactions, role of biotic components in the ecosystem, flow of material and energy in the ecosystem and ecological interdependence of organisms.

3.5 Development and Validation of Lesson Plans

The researcher developed 36 lesson plans which were according to the sub-topics of above mentioned three topics. Lesson plans of experimental groups (Appendix1) were planned to imply nine components of intellectual standards of Paul-Elder's critical thinking model through the collaborative teaching method but the lesson plans of control groups (Appendix 2) were reflected through the conventional teaching method. Herbartian model of lesson plans was adopted because the format of this model was appropriate to the nature of this experiment. All the lesson plans were validated through the opinions of the experts. The researcher has taken the classes of experimental groups by himself but the control groups were taught by the school teachers of biology in the light of developed lesson plans.

3.5.1 Lesson plans of experimental groups and control groups.

The concerned school teachers and the researcher has taken classes of control and experimental groups respectively having the same content, same component, and same format on the same day in the particular classrooms. Herbarian model of the lesson plan consists of 5-steps. The format of these steps was applied to develop the lesson plans of the experimental and control group of this study. J.F. Herbart (1776-1841) and his followers used this model for the development of lesson plans. (Retrieved from www.freenaleen.blogspot.in/2013/12/lesson-plan-steps-

herbartian-pproach.html) on April, 2019.There are following 5-steps used in this model as follow:

i. **Preparation/ introduction:** Teacher asks some questions from the students to check the previous knowledge and to produce interest to learn the topic.

ii. **Statement of aim**: Teacher writes the topic on the board and shares the objectives of the topic.

iii. **Presentation:** Presentation reflects the cooperative learning in the class room. Teacher motivates and stimulates the cognitive development of students by giving them chances to learn by themselves and questioning. Teacher compares and associates the facts, events and application of taught knowledge within subject and also with other subjects.

iv. **Generalization:** After taking the session, teacher provides opportunity to the students to think and recapitulate the topic. This step was termed as "system" by J.F. Herbart.

v. **Application:** It is basically the review of the knowledge. Teacher wants to know the depth of the acquired knowledge of present topic. Questions were recapitulated or giving chance to apply the acquired knowledge in new situation.

3.6 Research Instrument

The researcher developed the research instrument named Students Achievement Test (SAT) with the help of the supervisor and co-supervisor based on nine intellectual standards of Paul-Elder's Critical Thinking Model. SAT was consisted of 36 multiple-choice questions (MCQs) and one long essay question item (LEQ). This research instrument was used for both pre-test and post-test in the

experimental and control groups. (Appendix3). Saunders (2014) in Liberty University for the degree doctor of education used MCQs as an instrument for critical thinking and academic achievement. Following steps were taken to develop this tool:

3.6.1 Table of specification

Table of specification was prepared by the researcher by using already selected three chapters 17, 18, and 19. Table of specification (Appendix7) has the representation of proportionate test items for nine intellectual standards each of the selected chapters. All the nine intellectual standards (mentioned in chapter1) were planned in the table of specification. Two items for each intellectual standard were allocated from chapter No.17 "genes and inheritance", and one Long Essay Question (LEQ) was also assigned from this chapter due to its importance and the extent of the content. One test item related to each intellectual standard was assigned from chapter No.18 and chapter No.19.

3.6.2 Construction of the test items.

Eighteen MCQs and one Long Essay Question (LEQ) from chapter No.17, Nine MCQs from chapter No.18, and Nine MCQs from chapter No.19 were developed in the light of the intellectual standards of Paul-Elder's critical thinking model. Through adopting this procedure test items of the instrument were developed. The researcher applied the nature of questions present in the textbook of biology and O-level.

3.6.3 Validity of the instrument.

Gay and et al (2012) defined validity of research instrument as follow;

"Validity refers to the degree to which a test measures what it is supposed to measure. When we test, we test for a purpose, and our measurement tools must help us achieve

that purpose". (p160) All the test items were improved by the expert opinions, because a good instrument must not only be reliable but also be valid. Student Achievement Test (SAT) is validated through construct, content and criterion validity (Creswell, 2014).

i. Construct validity: Construct validity was assessed by the university teachers the experts of assessment. According to the opinions of experts, items were modified and decided the specific items to measure the intellectual standards.

ii. Content validity: Content relevance, content coverage and content representativeness are the related concepts of content validity. (Appendix 8)

Table 3.4

Content validity of Student Achievement Test (SAT)

Content validity	
Content relevance	Content relevance means each item should relate to the objectives. Each item in the student achievement test was related with the particular intellectual standard (Appendix 8& 9).
Content coverage	Content coverage represents the concepts or attributes covered by the items. Table of specification covers all the concepts
content representativeness	The number of items on each objective or attribute represents the content representativeness. Table of specification represent the number of items representing the intellectual standards.

iii. Criterion validity: Correlation of the scale with some other measure of the same construct / attribute under study is the criterion validity. Critical Thinking Test (CTT) developed and applied (13-15 age students) by Khalid Hamoud Alosaimi on 2013 for his Ph.D study in University of Dundee. This tool was already permitted for the use of non commercial and study research. The

constructs of CTT items required the answers of what, why and how about the information, which matched the items of SAT of this study. More over the constructs were validated by the experts (Alosaimi, 2013). The Critical thinking test (CTT) was applied for this study with the pilot testing of SAT to check the correlation of critical thinking in the students of class 10th. Twenty students from each high school (male and female) were randomly selected for pilot testing in Quetta city. (Appendix 4)

Table 3.5
Descriptive statistics of criterion validity(Male pilot testing)

	Mean	Std. Deviation	N
pre-test	4.7000	1.49032	20
critical thinking test	3.6500	1.03999	20

This table No.3.5 indicates the mean score of pre-test and critical thinking test and shows the normal distribution of twenty male students during pilot testing.

Table 3.6 Spearman Correlations of pre-test and critical thinking test (Male pilot testing)

Table 3.6
Spearman Correlations of pre-test and critical thinking test (Male pilot testing)

		pre-test	critical thinking test
pre-test	Pearson Correlation	1	.540*
	Sig. (2-tailed)		.014
	N	20	20
critical thinking test	Pearson Correlation	.540*	1
	Sig. (2-tailed)	.014	
	N	20	20

*. Correlation is significant at the 0.014 level (2-tailed).

Table 3.6 demonstrates significance and positive relationship between ability of critical thinking and SAT in pilot testing [r (20) = .540, p = .014 < .05]. Pre-test and critical thinking test has a moderate relationship (0.4-0.6) (yousufzai, 2017).

Table 3.7

Descriptive statistics of criterion validity(Female pilot testing)

	Mean	Std. Deviation	N
pre-test	6.4000	1.39170	20
Critical thinking test	5.6500	1.92696	20

Table 3.7 shows the mean of pre-test and critical thinking test having normal distribution of twenty female students during pilot testing.

Table 3.8

Spearman Correlations of pre-test and critical thinking test (Female pilot testing)

		pre-test	Critical thinking test
pre-test	Pearson Correlation	1	.604**
	Sig. (2-tailed)		.005
	N	20	20
Critical thinking test	Pearson Correlation	.604**	1
	Sig. (2-tailed)	.005	
	N	20	20

**. Correlation is significant at the 0.005 level (2-tailed).

Table No. 3.8 demonstrates significance and positive relationship between ability of critical thinking and SAT in pilot testing [r (20) = .604, p = .005 < .05].

3.6.4 Reliability of instrument.

"Reliability is the degree to which a test consistently measures whatever it is measuring" (Gay, et al. 2012. P.164).The split-half method was applied to test the reliability of the test items. For the split-half method Students' Achievement Test was applied for pilot testing. In this connection, twenty students of class 10^{th} were selected randomly from each selected school. This method is used to test the correlation between the even and odd numbers of test items in the instrument for its reliability through coefficient alpha. So the reliability coefficient alpha of both schools reflects

that the research instrument was reliable because the coefficient alpha of test items used for pilot testing in government boys' high school and government girls' high school remained 0.803 and 0.77 respectively

3.6.5 Marking of test items.

The marking scheme for MCQs was developed by the researcher in such a way that one mark was assigned to each correct answer which is the international standard. The research instrument contains one Long Essay Question (LEQ) that was marked with the help of a Rubric. The researcher developed this rubric for one LEQ (Appendix 9).

3.7 Explanation and schedule of the experiment

The experiment was conducted by the researcher in two government high schools (male and female). Both schools are running under the management of the Directorate of Schools, Department of Education, Government of Balochistan, Quetta. Government High school (boys) satellite town Quetta and Government High school (girls) satellite town, Quetta were selected for completing the experiment. The distance between both the schools is less than one kilometre, which was easy for the researcher to conduct the experiment at both schools in the same day. The study was conducted from September to November 2019 because from the mid of December, the winter vacations start and end at the end of February in Quetta. Therefore it was impossible to delay the experiment in the schools. Class 10^{th} annual examination usually starts soon after the winter vacation. Furthermore, the administration and school teachers were working consciously to complete their syllabi before winter vacation. Administration of the schools assigned 2nd period in government boys' high school, started from 9.50 am to 10.30 am and 7th period in government girls' high school started from 12.30 pm to 1.10 pm without changing the schedule or time table

of the school. But they adjusted separate classrooms for experimental groups. The researcher received written permission from the Director of Schools Balochistan. (Appendix 10)

Detail of the experiment is given below:

3.7.1 Duration of the experiment.

The researcher performed the experiment from September, 23 to November 21, 2019. According to the timetable of both selected schools, 40 minutes per day were specified for intervention in experimental and control groups. In this way experiment prolonged for eight weeks (5 days per week).

3.7.2 Instructional strategies of experimental groups.

Paul-Elder's critical thinking model can be applied to solve any issue by giving reasons. It is a general model used for all disciplines and everyday issues through applying thinking skills (Paul& Elder, 2010). Thinking skills can be developed through the collaborative teaching method (Gokhale, 1995). In the same fashion, Garcia and Pintrich (1992) suggested that collaboration in the classroom develops critical thinking skills. Moreover, teaching strategies were suggested by the National Research Council (1997) for the improvement and efficient learning of the students through applying general principles of learning. According to the planning of research, the researcher taught the students of experimental groups through collaborative teaching method by applying Paul-Elder's critical thinking model. Some factors were considered to do so:

i. It was risky for the researcher if the school teacher would teach the experimental group because the teachers of schools were not aware of Paul-Elder's critical thinking model.

ii. The researcher followed the example of Ph.D scholar Aziz-ur-Rehman (2011) who taught experimental group himself in his experimental study at International Islamic University, Islamabad.

iii. If the researcher of this study teaches both the experimental and control groups then he had to teach four classes per day which could create fatigue for the researcher and could slow down the smooth functioning of the experiment.

3.7.3 Instructional strategies of control groups.

The researcher designed a conventional teaching method for control groups. This type of teaching method was already practicing in government high schools of Balochistan. Therefore it was decided to continue the lecture method for the control groups. The same numbers of lesson plans (36) were delivered in the control groups by the school teachers in both schools. The researcher had been assured by the Principals for the strict administration during the particular and stated sessions of control groups. Biology school teachers applied following strategies of conventional teaching methods for the control groups. They have equal academic qualification (M.Sc Zoology) and teaching experience to the researcher (16years).

i. To encourage rote memorization

ii. To transfer the subject material through lecture and by using a white board

iii. There were poor interactive activities with teachers and among the students.

iv. The only textbook was used for teaching, formative assessment, and assigning homework

v. No collaborative work was assigned, only engaged the students in individual

vi. Students were forced to maintain and complete their notebooks

vii. To make the students physically passive and cognitively active

viii. To maintain a teacher-centred environment in the classroom

ix. Biological concepts were explained by the teachers through reading the textbook and dictating the diagrams and main points of the concept.

x. To neglect the individual differences of students and learning motivations.

xi. Teachers show anger to the students due to the poor interest, questioning during lecture, and asking permission to drink water and washroom during lecture.

Table 3.9
Instructional strategies for academic achievement

S.NO	Experimental Group Collaborative Teaching Method	Control Group Conventional Teaching Method
1	**Brain Storming** Think about prior knowledge: (Chin, Dohmen & Schwartz, 2013)	**Announcement of Topic** Topic will be announced connected with the previous topic.
2	**Think pair share**: Think pair and share is used for the collaboration and sharing in the class room. Students first think individually then share and discuss with the pair. (Biggs, 1996, Abrami et al., 2008; Lai, 2011). Paul and Elder (2007) suggest active and cooperative learning for critical thinking in thinkers guide for faculty.	**Lecture cum Demonstration** for fostering knowledge of students: (Halpern, 1998); Ennis, 1992; (Duron, Limbach, & Waugh, 2006).
3	**Socratic Questioning** Chaffee (2014) suggests that this needs the critical thinking skills in order to assess new information while Facione (1990) argues that there is a need to develop critical	**Solving Problems on the Board** Call students individually to fill the blank of the question. Always call the students with their names.

	thinking in students through cognitive skills and habits of inquiry. Paul and Elder(2008) suggest that the thinker who understands intellectual standards in disciplined reasoning asks questions that targets the assessment of thinking.	
4	**Assignments** Students will develop their portfolio of their assignments.	**Note Book** Students will dictate the notes and write the answer of questions on the note book.

3.7.4 Equal educational opportunities.

The researcher was bound to provide equal educational opportunities to the experimental and control groups. Following steps were taken for the purpose:

i. Time duration of teaching /day

ii. Subject matter or chapters of the textbook to teach

iii. Total number of lesson plans

iv. Administration time of students' achievement test

3. 8 Execution of Experiment

There were some steps taken to precede the experiment

3.8.1 Ethical consideration.

Before execution of the experiment, the consent forms and children assent forms were signed with the schools' principals (male and female) and the biology subject teachers (as a guardian) of class 10th respectively. Permission letter for the intervention was already taken from the Director Schools, the government of Balochistan, Quetta. Students were informed about the experimental research and were asked to take part in this experiment. The aim of study was to enhance deep concepts of biology and critical thinking skills. The researcher assured them that the secrecy and confidentiality of the institution (including the participants) will be

maintained. The information obtained will be kept securely and data will only be used by the research team for academic purposes (Fraenkel, Wallen & Hyun, 2012).

3.8.2 Administration of pre-test.

Before starting the intervention, SAT was administered as a pre-test on September 21, 2019. The scores collected from the pre-test were used to assess the academic ability of students in biology (see analysis in chapter No.4).

3.8.3 Teaching-learning sessions.

Teaching-learning sessions were conducted from September 23 to November 21, 2019. The intervention of 36 validated lesson plans was implemented through collaborative and conventional teaching methods for the experimental and control group respectively. This treatment was completed in eight weeks.

3.8.4 Variables' control in the study.

The intervention was held in two government high schools in Quetta city. The researcher has taken the following steps to decrease the effect of internal and external threats.

3.8.4.1 Control of internal threat.

The researcher has taken following steps to control the internal threats of the experiment.

i. **History**: Experiments of the study continued for eight weeks. No incident happened during this period that might influence the academic achievement of the students.

ii. **Testing**: One threat of testing can be the textbook-based test which may be familiar to the student and can affect the validity of the results. Therefore researcher developed the instrument based on intellectual standards of critical

thinking model was content-based and quite new for the students. The second threat of testing was the time duration of the experiment. For this purpose, two months duration is enough to forget the unseen items of the pre-test. Moreover, the subjects were not aware of the conduction of the post-test at the end.

iii. **Developing of instrument:** Students achievement test (SAT) was validated and reliability was taken before administering it on the students to avoid the threat of instrumentation.

iv. **Mortality:** This experiment was limited to eight weeks which is not a long period. In addition, the cooperation of school management and the interest of the students also made sure that no student remained absent during the study

3.8.4.2 External validity of the experiment.

External threats were controlled by the researcher by taking following steps:

i. **Interference of multiple treatments:** There is a chance to take a coaching class as extra treatment by the subjects instead of the researcher or the subjects who were already involved in any related research study which can interfere with the true results of the experiment. School teachers in Quetta city were unaware of the intellectual standards of Paul-Elder's critical thinking model, so it was not a risk of interference of treatment. Moreover, the researcher applied a single treatment in both experimental and control groups.

ii. **Selection of students**: Simple random sampling was used for the selection of the subjects to avoid subjectivity. Furthermore, the pairing technique was applied to allocate and equalize the subjects in experimental and control groups.

iii. **Specificity of variables:** All the procedural steps were taken to avoid external threats. Lesson plans were validated; SAT was pilot tested and randomly administered. Due to such specificities, it was tried to avoid this threat. There was no gap between the end of experimentation and post-test. All the criteria of the experiment were well defined like pre-test, post-test, rubric, applying of intellectual standards through collaborative teaching method, and duration of intervention.

iv. **Experimenter Effects:** The perception of Paul-Elder's critical thinking model is not present in our educational set up and our teachers in schools were unaware of this model. It might remain a gap in training and implementation if the school teachers were trained to Paul-Elder's critical thinking model and to allow teaching experimental group. The researcher had been studying this model for about three years and having a deep understanding of this model through respected university teachers, literature, watching video clips of Richard Paul and Linda Elder, and interacting with critical thinking experts. To avoid any gap in the experiment, the researcher planned to teach experimental groups himself by applying the intellectual standards of this model. Marking biasness of SAT was controlled through marking schemes and rubrics. Moreover, different variables were controlled by equating their effects in experimental and control groups like time and place of intervention, duration of the class, number of lesson plans, subject material, students of mixed ability, the timing of pre-test and post-test.

v. **Reactive arrangements:** Researcher may create an experimental environment that is highly artificial and not easily generalizable to non-experimental settings is called the reactive arrangement (Gay, et al, 2012). School teachers

taught the students of control groups and these students did not know about the comparison with the experimental group to minimize the John Henry effect on the study. The duration of eight weeks of study was useful to control the Hawthorne effect because an individual can positively change their behaviour for a short period. Therefore placebo effect (psychological effect) was controlled by this action.

3.8.6 Conduction of post test.

The post-test was administered to the next day of the last session of intervention on November 21, 2019. Achievement scores of all the students were calculated by subtracting the pre-test scores from post-test scores

3.9 Data analyses

Data and its analyses were described as following

i) **Annual Examination Scores (AES):** Biology scores are the data achieved by the students in the annual examination of class 9^{th} held in 2019. The scores of the students were taken from the record of the school.

ii) **Students' achievement test (SAT)**: SAT was administered as a pre-test before starting the experiment. The scores obtained from the pre-test were another type of data of this study.

iii) **Critical Thinking Test (CTT):** CTT was developed and applied by Khalid Hamoud Alosaimi in 2013 at the University of Dundee, the UK in his Ph.D. study. This test was conducted with a pre-test to check the criterion validity of the research instrument.

iv) **Students' achievement test (SAT):** SAT was administered as a post-test on the next day of the last session of the intervention. The scores achieved by the students were named post-test scores.

v) The scores achieved from the difference of pre-test scores and post-test scores were called achievement scores.

vi) All the data were analyzed through descriptive and inferential analysis. Dependent and independent t-tests were applied to compare the mean scores of the same group and counterpart respectively.

vii) ANOVA (Analysis of variance) was applied to test the variance of different ability level students in the experimental and control groups.

viii) The split-half method was applied for the reliability of SAT. Pearson's correlation examined the consistency between the odd and even items of the SAT.

Statistical package for social sciences (SPSS) V.20 was used to apply the statistical tests. The results were taken from the analyses of data. The researcher concluded the result and suggested the recommendations.

Chapter No.4

Analyses of Data and Interpretation

The present study aimed to find out the effectiveness of Paul-Elder's critical thinking model through collaborative teaching method in biology at the secondary level. It also aimed to compare the students' academic achievement across experimental and control groups. For this purpose, the collected data through students' achievement test (SAT) were analyzed using Statistical Package for Social Sciences (version 20). Steps that have been taken to analyze the data are discussed below.

Exploratory analysis was used to identify the normality of the data. In this connection, first of all, hard copies of the answer sheets of pre-test and post-tests were coded to avoid any mixing and missing of the data. Template of SPSS (V-20) was developed to enter the data. Data were entered and the cleaning process was completed by the researcher to avoid any mistake in the entry of data. In this connection, frequencies were run to detect the errors. The errors were identified and rectified accordingly. To investigate the normality of distribution, a rule of thumb was used that is the data would be normal if the value of skewness is less than double the value of the standard error of the skewness. Then the distributions of the data were explored and the value of skewness was found less than the value of double of standard error. So the distribution was found normal all over and across the groups (Annex 11&12).

Descriptive analysis was used to calculate the central tendency and variation. In addition, inferential analysis was applied to the data to compare the academic achievement of students within and across the groups. The significance level (0.05) was applied in the comparison of the groups for the acceptance or rejection of the

hypotheses. Furthermore, Effect sizes for the differences were also computed to gauge the magnitude of the differences between experimental and control groups. The effect size was computed through the formula $r = \sqrt{\frac{t^2}{t^2+df}}$ where r represents the effect size and interpreted in light of literature (Field, 2018; p.609) who suggests the range of effect size as presented in table 4.

Table 4: *Range of effect size (Field, 2018)*

Range of effect size	**Effect size**
0.1- 0.29	Small
0.3- 0.49	Medium
0.5------	Large

Analyses and interpretation of data were described as follow:

4.1 Comparison of Experimental and Control Groups before Intervention

Data received from the pre-test of experimental and control groups before intervention. The data were analyzed to test the knowledge of the sample in 10^{th}-grade biology before the intervention, based on the intellectual standards of Paul-Elder's critical thinking model.

4.1.1 Comparison of male experimental and control groups before intervention

Table 4.1

Experimental and Control group(male) Pre-test mean and independent t-test

	Male	N	Mean	Std. Deviation	Difference (t (df)= t value; P value)
pre test score male	Experimental	36	4.77	1.26	t (70)= 0.34; p = 0.73
	Control	36	4.66	1.47	

Table 4.1 indicates the same number of students in experimental and control groups who were tested prior to the instruction. In addition the scores of pre-test in experimental group were 0.11 greater on average than the scores of control group. The students of experimental group achieved an average of 4.77 scores and the students of control group having on average of 4.66 scores. More over the mean scores of standard deviation in experimental and control groups consisted of 1.26 and 1.47 respectively. The experimental group data having a higher standard deviation tells me that the experimental group data is less spread out or dispersed than the control group. The significance level of the difference remains 0.73 which is more than alpha value (0.05). ($t(70)= 0.34; p > 0.05$)

As a result the value of significant level indicates that there was no significant difference in mean scores of both groups before the intervention. Hence forth it was concluded that according to the pre-test scores the male subjects of both experimental and control groups remained equal in achievement of critical thinking based on Paul-Elder's critical thinking model.

4.1.2 Comparison of female experimental and control groups before intervention

Table 4.2

Experimental and Control group(female) Pre-test mean and independent t-test

	Male	N	Mean	Std. Deviation	Difference (t (df)= t value; P value)
pre test score male	Experimental	36	4.64	1.39	t (70)= 0.08; p = 0.93
	Control	36	4.63	1.37	

Table 4.2 indicates that the mean scores of pre-test in experimental and control groups were 4.64 and 4.63 respectively. There was a difference of 0.01 in the mean

scores of both groups before the intervention which is a little difference of scores in both groups. More over the mean scores of standard deviation in experimental and control group consisted of 1.39 and 1.37 respectively. The experimental group data having a higher standard deviation shows that the experimental group data is more spread out or dispersed than the control group. The significance level of the difference remains 0.93 which is more than alpha value (0.05). ($t(70)= 0.08$; $p > 0.05$)

As a result the value of significant level indicates that there was no significant difference in mean scores of both groups before the intervention. Hence forth it was concluded that according to the pre-test scores the female subjects of both experimental and control groups remained equal in achievement of critical thinking based on Paul-Elder's critical thinking model.

4.2 Academic Achievement of Male Experimental and Control Groups

4.2.1 Academic achievement of male experimental group.

Table 4.3

Experimental group(male) pre-test post-test mean (Paired Samples Statistics)

		Mean	N	Std. Deviation	Correlation (sig)	Sig. (2-tailed)
Pair 1	Post test	34.77	36	4.63	0.59 (0.73)	0.00
	Pre test	4.77	36	1.26		

Table 4.3 indicates that there were 36 subjects in the experimental male group. The academic achievement was calculated through the difference of scores in pre-test and post- test. In this way mean scores of pre-test and post- test were 4.77 and 34.77 respectively. Standard deviation mean scores of pre-test was 1.26 and post test was 4.63 which tells that post-test scores data is more dispersed than the pre-test. The means of results indicate that there was improvement in the students after the treatment. The correlation in the pre-test and post-test scores of 36 students in

experimental group was 0.112 with a significance of 0.73 which is a positive correlation indicating to increase the academic achievement of the sample.

The difference of mean scores in male experimental group in pre-test and post-test, was calculated in to 30.00. Furthermore, the level of significance is 0.00 which is less than alpha value. In this connection the significant value which is less than alpha value (0.05) indicates the significant difference of academic achievement of the experimental group students before and after the intervention.

4.2.2 Academic achievement of male control group.

Table 4.4

Control group(male) pre-test post-test mean (Paired Samples Statistics)

		Mean	N	Std. Deviation	Correlation (sig)	Sig. (2-tailed)
Pair 1	Post test	24.05	36	4.42	0.12 (0.46)	0.00
	Pre test	4.66	36	1.47		

It is obvious from table 4.4 that there were 36 students in the control male group. The academic achievement was calculated through the difference of scores in pre-test and post-test. The means of results indicate that there was improvement in the students after the intervention. In this way, mean scores of pre-test and post- test were 4.66 and 24.05 respectively. Standard deviation mean scores of pre-test was 1.47 and post-test was 4.42 which indicates that the scores data of post -test is more spread than pre-test and having a large variation of scores in the post-test. The correlation in the pre-test and post-test scores of 36 students in control group was 0.12 with a significance of 0.46 which is a positive correlation indicating to increase the academic achievement of the sample.

The difference of mean scores in male control group in pre-test and post-test was calculated in to 19.39. Furthermore, the level of significance is 0.00 which is less than alpha value. In this connection the significant value which is less than alpha

value (0.05) indicates the significant difference of academic achievement of students in the control group, before and after the intervention.

4.3 Academic Achievement of Female Experimental and Control Groups

4.3.1 Academic achievement of female experimental group.

Table 4.5

Experimental group(female) pre-test post-test mean (Paired Samples Statistics)

		Mean	N	Std. Deviation	Correlation (sig)	Sig. (2-tailed)
Pair 1	Post test	36.94	36	3.40	0.20 (0.24)	0.00
	Pre test	4.66	36	1.39		

Table 4.5 shows that there were 36 subjects in the experimental female group. The academic achievement was calculated through the difference of scores in pre-test and post- test. In this way mean scores of pre-test and post- test were 4.66 and 36.94 respectively. Standard deviation mean scores of pre-test was 1.39 and post test was 3.40 which tells that the scores data of post -test is more spread than pre-test and having a large variation of scores in the post-test. The means of results indicate that there was improvement in the students after the treatment. The correlation in the pre-test and post-test scores of 36 students in experimental group was 0.20 with a significance of 0.24 which is a positive correlation indicating to increase the academic achievement of the sample.

The difference of mean scores in female experimental group in pre-test and post-test, was calculated in to 32.28. In addition, the level of significance is 0.00 which is less than alpha value. In this connection the significant value which is less than alpha value (0.05) indicates the significant difference of academic achievement of the experimental group students before and after the intervention.

4.3.2 Academic achievement of female control group.

Table 4.6

Control group(female) pre-test post-test mean (Paired Samples Statistics)

		Mean	N	Std. Deviation	Correlation (sig)	Sig. (2-tailed)
Pair 1	Post test	24.05	36	3.37	-0.032 (0.85)	0.00
	Pre test	4.63	36	1.37		

Table 4.6 shows that there were 36 subjects in the control female group. The academic achievement was calculated through the difference of scores in pre-test and post- test. In this way mean scores of pre-test and post- test were 4.63 and 24.05 respectively. Standard deviation mean scores of pre-test was 1.37 and post test was 3.37 which indicates that the scores data of post -test is more spread than pre-test and having a large variation of scores in the post-test. The means of results indicate that there was improvement in the students after the treatment. The correlation in the pre-test and post-test scores of 36 students in experimental group was -0.032 with a significance of 0.85 which is a positive correlation indicating to increase the academic achievement of the sample.

The difference of mean scores in female control group in pre-test and post-test, was calculated in to 19.42. In addition, the level of significance is 0.00 which is less than alpha value. In this connection the significant value which is less than alpha value (0.05) indicates the significant difference of academic achievement of the control group students before and after the intervention.

4.5 Comparison of Academic Achievement in Experimental and Control Groups

4.5.1 Comparison of academic achievement in male experimental and control Groups

Table 4.7

Comparison of academic achievement by male groups

Groups	Mean	Standard Deviation	Difference (t (df) = t value; P value)	Effect size (r)
Experimental	34.77	4.63	t (70)= 10.04; p<0.001	0.76
Control	24.05	4.42		

The entries of table 4.7 indicate that the number of students were same in male experimental and control groups. The post-test mean scores of experimental and control groups are 34.77 and 24.05 respectively having a difference of 10.72 on average. `It implies that there was a difference in academic performance of both groups. Moreover, this table explains the values of standard deviation which are 4.63 and 4.42 respectively. It tells me that the scores data of experimental group is more spread than control group.

The t value is 10.04 and the significance level is 0.000. [t (70) = 10.04; P< 0.001; r=0.76]. The above mentioned calculations of this table confirm that there was a significant difference in the academic achievement of both groups. Furthermore the magnitude of significant difference was computed to calculate the effect size. So the value of effect size remained 0.76 and the magnitude of difference was large.

4.5.2 Comparison of academic achievement in female experimental and control Groups

Table 4.8

Comparison of academic achievement by female groups

Groups	Mean	Standard Deviation	Difference (t (df) = t value; P value)	Effect size (r)
Experimental	36.94	3.40	t (70)= 16.13; p<0.001	0.88
Control	24.05	3.37		

Table 4.8 points out that the post-test mean scores of female experimental and control groups are 36.94 and 24.05 respectively having a difference of 12.89 on average. It shows that students in experimental group achieved better than control group. Moreover, the mean scores of standard deviation in experimental and control groups are 3.40 and 3.37 respectively which inform that the scores data of experimental group is more spread than control group.

This table also demonstrate that t value is 16.13 and the significance level is 0.000. [t (70) = 16.13; P< 0.001; r=0.88]. The above mentioned calculations of this table confirm that there was a significant difference in the academic achievement of both groups. Furthermore the magnitude of significant difference was computed to calculate the effect size. So the value of effect size remained 0.88 and the magnitude of difference was large.

4.8 Significant difference of intellectual standards in experimental and control groups (Hypotheses H01 to H09)

4.8.1 Significant difference of intellectual standards in male experimental and control groups.

To analyze the hypotheses following analytical steps have been taken:

H01: There is no significant difference of academic achievement mean score in biology in experimental and control groups based on"clarity"

Table 4.9

Significance difference of academic achievement in "clarity" by male groups

Intellectual Standard	Groups	Mean	Standard Deviation	Difference (t (df)= t value; P value)	Effect size (r)
Clarity	Experimental	4.55	0.69	t (70)= 0.37; p = 0.71	0.04
	Control	4.50	0.56		

Table 4.9 indicates the same number of male students in the experimental and control groups. Mean scores of the experimental and control groups for "Clarity" are 4.55 and 4.50 respectively. The above mentioned calculations of this table indicate that there is a difference of 0.05 in mean scores of the post-test which is a very little difference. By the same token, the values of standard deviation in the experimental and control groups are 0.69 and 0.56 respectively. The experimental group data having a somewhat higher standard deviation tells me that the data of experimental group is more spread out or dispersed than the control group.

The above mentioned calculations in table 4.9 shows that the t value is 0.37 and the level of significance is 0.71, which is more than alpha value 0.05. [t (70) = 0.37; P> 0.05; r=0.04]. Magnitude of difference was computed to calculate the effect size. So the value of effect size remained 0.04 and magnitude of the difference was small. In this connection the results imply that there is no significant difference in both the experimental and control groups in achievement of "Clarity", one of the basic intellectual standard in Paul-Elder's critical thinking model. Therefore null hypothesis (H01) was accepted because there is no significant difference in the achievement of "Clarity" in the experimental and control groups.

H02: There is no significant difference of academic achievement mean score in biology in experimental and control groups on the bases of "Accuracy"

Table 4.10

Significance difference of academic achievement in "Accuracy" by male groups

Intellectual Standard	Groups	Mean	Standard Deviation	Difference (t (df)= t value; P value)	Effect size (r)
Accuracy	Experimental	4.33	0.71	t (70)= 0.51; p = 0.60	0.06
	Control	4.25	0.64		

Table 4.10 shows mean scores of the experimental and control groups for "Accuracy" are 4.33 and 4.25 respectively having a little difference of 0.08 on average. By the same token, the values of standard deviation in experimental and control groups are 0.71 and 0.64 respectively. It implies that the scores data of experimental group is more spread than control group.

The t value is 0.51 and the level of significance is 0.601, which is more than alpha value 0.05. [t (70) = 0.51; P> 0.05; r=0.06]. Magnitude of the difference was computed to calculate the effect size. So the value of the effect size remained 0.06 and magnitude of the difference was small. In this connection, the results imply that there is no significant difference in both the experimental and control groups in achievement of "Accuracy", the intellectual standard in Paul-Elder's critical thinking model. Therefore null hypothesis (H02) was accepted because there is no significant difference in achievement of "Accuracy" in the experimental and control groups.

H03: There is no significant difference of academic achievement mean score in biology in experimental and control groups on the bases of "Precision".

Table 4.11
Significance difference of academic achievement in "Precision" by male groups

Intellectual Standard	Groups	Mean	Standard Deviation	Difference (t (df)= t value; P value)	Effect size (r)
Precision	Experimental	3.97	0.69	t (70)= 3.71; p < 0.001	0.40
	Control	3.30	0.82		

Table 4.11 indicates that the mean scores of experimental and control groups for "Precision" are 3.97 and 3.30 respectively with a difference of 0.67. Moreover, the values of standard deviation in experimental and control groups are 0.69 and 0.82. It indicates that the score data of experimental group is less spread out than control group.

The t value is 3.71 and the level of significance is 0.000, which is less than alpha value 0.05. [t (70) = 3.71; P< 0.001; r=0.40]. The magnitude of difference was computed to calculate the effect size. So the value of effect size remained 0.40 and magnitude of the difference was medium. In this connection the results imply that there is a significant difference in both experimental and control groups in the achievement of "precision". Therefore null hypothesis (H03) was rejected due to the significant difference in experimental and control groups for the achievement of "precision".

H04: There is no significant difference of academic achievement mean score in biology in experimental and control groups on the bases of "Relevance".

Table 4.12

Significance difference of academic achievement in "Relevance" by male groups

Intellectual Standard	Groups	Mean	Standard Deviation	Difference (t (df)= t value; P value)	Effect size (r)
Relevance	Experimental	3.72	0.77	t (70)= 7.08; p < 0.001	0.64
	Control	2.27	0.94		

Table 4.12 clears that the mean scores of experimental and control groups for "Relevance" are 3.72 and 2.27 respectively having a difference of 1.45 on average. Moreover, the values of standard deviation in experimental and control groups are 0.77 and 0.94 respectively. It shows that scores data of control group is more spread out than experimental group.

Moreover the t value is 7.08 and the level of significance is 0.000, which is less than alpha value 0.05. [t (70) = 7.08; P< 0.001; r=0.64]. The magnitude of difference was computed to calculate the effect size. So the value of effect size remained 0.64 and magnitude of the difference was large. In this connection the results imply that there is a significant difference in both experimental and control groups in the achievement of "Relevance". Therefore null hypothesis (H04) was rejected due to the significant difference in experimental and control groups for the achievement of "Relevance".

H05: There is no significant difference of academic achievement mean score in biology in experimental and control groups on the bases of "Depth".

Table 4.13

Significance difference of academic achievement in "Depth" by male groups

Intellectual Standard	Groups	Mean	Standard Deviation	Difference (t (df)= t value; P value)	Effect size (r)
Depth	Experimental	3.30	0.78	t (70)= 9.36; p < 0.001	0.74
	Control	1.69	0.66		

Table 4.13 summarises that the mean scores of experimental and control groups for "depth" are 3.30 and 1.69 respectively having a difference of 1.61 on average. Moreover, the values of standard deviation in experimental and control groups are 0.78 and 0.66 respectively. It informs me that scores data of experimental group is more spread out than control group.

Moreover the t value is 9.36 and the level of significance is 0.000, which is less than alpha value 0.05. [t (70) = 9.36; P< 0.001; r=0.74]. The magnitude of difference was computed to calculate the effect size. So the value of effect size remained 0.74 and magnitude of the difference was large. In this connection the results imply that there is a significant difference in both experimental and control groups in the achievement of "Depth". Therefore null hypothesis (H05) was rejected due to the significant difference in experimental and control groups for the achievement of "Depth".

H06: There is no significant difference of academic achievement mean score in biology in experimental and control groups on the bases of "Logic".

Table 4.14

Significance difference of academic achievement in "Logic" by male groups

Intellectual Standard	Groups	Mean	Standard Deviation	Difference (t (df)= t value; P value)	Effect size (r)
Logic	Experimental	3.11	0.94	t (70)= 8.84; p < 0.001	0.72
	Control	1.19	0.88		

Table 4.14 indicates that the mean scores of experimental and control groups for "logic" are 3.11 and 1.19 respectively having a difference of 1.92 on average. Moreover, the values of standard deviation in experimental and control groups are 0.94 and 0.88 respectively which indicates that scores data of experimental group is more spread out than control group.

Moreover the t value is 8.84 and the level of significance is 0.000, which is less than alpha value 0.05. [t (70) = 8.84; P< 0.001; r=0.72]. The magnitude of difference was computed to calculate the effect size. So the value of effect size remained 0.72 and magnitude of the difference was large. In this connection the results imply that there is a significant difference in both experimental and control groups in the achievement of "logic". Therefore null hypothesis (H06) was rejected due to the significant difference in experimental and control groups for the achievement of "logic".

H07: There is no significant difference of academic achievement mean score in biology in experimental and control groups on the bases of "Breadth".

Table 4.15

Significance difference of academic achievement in "Breadth" by male groups

Intellectual Standard	Groups	Mean	Standard Deviation	Difference (t (df)= t value; P value)	Effect size (r)
Breadth	Experimental	3.72	0.56	t (70)= 9.12; p < 0.001	0.73
	Control	2.33	0.71		

Table 4.15 indicates that the mean scores of experimental and control groups for "Breadth" are 3.72 and 2.33 respectively having a difference of 1.39 on average. Moreover, the values of standard deviation in experimental and control groups are 0.56 and 0.71 respectively. It implies that scores data of control group is less spread than control group.

Moreover the t value is 9.12 and the level of significance is 0.000, which is less than alpha value 0.05. [t (70) = 9.12; P< 0.001; r=0.73]. The magnitude of difference was computed to calculate the effect size. So the value of effect size remained 0.73 and magnitude of the difference was large. In this connection the results imply that there is a significant difference in both experimental and control groups in the achievement of "Breadth". Therefore null hypothesis (H07) was rejected due to the significant difference in experimental and control groups for the achievement of "Breadth".

H08: There is no significant difference of academic achievement mean score in biology in experimental and control groups on the bases of "significance".

Table 4.16

Significance difference of academic achievement in "significance" by male groups

Intellectual Standard	Groups	Mean	Standard Deviation	Difference (t (df)= t value; P value)	Effect size (r)
Significance	Experimental	4.02	0.69	t (70)= 11.20; p < 0.001	0.80
	Control	2.25	0.64		

Table 4.16 indicates that the mean scores of experimental and control groups for "significance" are 4.02 and 2.25 respectively having a difference of 1.77. Moreover, the values of standard deviation in experimental and control groups are 0.69 and 0.64 respectively. It indicates that score data of experimental group is little more spread than control group.

Moreover the t value is 11.20 and the level of significance is 0.000, which is less than alpha value 0.05. [t (70) = 11.20; P< 0.001; r=0.80]. The magnitude of difference was computed to calculate the effect size. So the value of effect size remained 0.80 and magnitude of the difference was large. In this connection the results imply that there is a significant difference in both experimental and control groups in the achievement of "significance". Therefore null hypothesis (H08) was rejected due to the significant difference in experimental and control groups for the achievement of "significance".

H09: There is no significant difference of academic achievement mean score in biology in experimental and control groups on the bases of "Fairness".

Table 4.17

Significance difference of academic achievement in "Fairness" by male groups

Intellectual Standard	Groups	Mean	Standard Deviation	Difference (t (df)= t value; P value)	Effect size (r)
Fairness	Experimental	4.02	0.69	t (70)= 10.27; p < 0.001	0.77
	Control	2.25	0.76		

Table 4.17 indicates that the mean scores of experimental and control groups for "Fairness" are 4.02 and 2.25 respectively having a difference of 1.97 on average. Moreover, the values of standard deviation in experimental and control groups are 0.69 and 0.76 respectively. It implies that score data of experimental group is less spread out than control group.

Moreover the t value is 10.27 and the level of significance is 0.000, which is less than alpha value 0.05. [t (70) = 10.27; P< 0.001; r=0.77]. The magnitude of difference was computed to calculate the effect size. So the value of effect size remained 0.77 and magnitude of the difference was large. In this connection the results imply that there is a significant difference in both experimental and control groups in the achievement of "Fairness". Therefore null hypothesis (H09) was rejected due to the significant difference in experimental and control groups for the achievement of "Fairness".

4.8.2 Significant difference of intellectual standards in female experimental and control groups.

To analyze the hypotheses in the female groups following analytical steps have been taken

H01: There is no significant difference of academic achievement mean score in biology in experimental and control groups on the bases of "Clarity".

Table 4.18

Significance difference of academic achievement in "clarity" by female groups

Intellectual Standard	Groups	Mean	Standard Deviation	Difference (t (df)= t value; P value)	Effect size (r)
Clarity	Experimental	4.94	0.47	t (70)= 1.71; p = 0.09	0.20
	Control	4.72	0.61		

Table 4.18 indicates mean scores of the experimental and control groups for "Clarity" are 4.94 and 4.72 respectively having a difference of 0.22 on average. By the same token, the values of standard deviation in the experimental and control groups are 0.47 and 0.61 respectively. It indicates that score data in experimental group is less spread out than control group.

More over the t value is 1.71 and the level of significance is 0.09, which is more than alpha value 0.05. [t (70) = 1.71; P> 0.05; r=0.20]. The magnitude of difference was computed to calculate the effect size. So the value of effect size remained 0.20 and magnitude of the difference was small. In this connection the results imply that there is no significant difference in both the experimental and control groups in achievement of "Clarity". Therefore null hypothesis (H01) was accepted in female groups because there is no significant difference in the achievement of "Clarity" in the experimental and control groups.

H02: There is no significant difference of academic achievement mean score in biology in experimental and control groups on the bases of "Accuracy".

Table 4.19

Significance difference of academic achievement in "Accuracy" by female groups

Intellectual Standard	Groups	Mean	Standard Deviation	Difference (t (df)= t value; P value)	Effect size (r)
Accuracy	Experimental	4.55	0.55	t (70)= 2.31; p = 0.023	0.26
	Control	4.27	0.45		

According to table 4.19, mean scores of the experimental and control groups for "Accuracy" are 4.55 and 4.27 respectively having a difference of 0.28 on average. In addition, the values of standard deviation in the experimental and control groups are 0.55 and 0.45 respectively. It shows that score data of Accuracy in experimental group is more spread than control group.

More over the t value is 2.31 and the level of significance is 0.02, which is less than alpha value 0.05. [t (70) = 1.71; P< 0.05; r=0.26]. The magnitude of difference was computed to calculate the effect size. So the value of effect size remained 0.26 and magnitude of the difference is small but significant difference was found in both the experimental and control groups in achievement of "Clarity". Therefore null hypothesis (H02) was rejected in female groups because there is significant difference in achievement of "Clarity" in the experimental and control groups.

H03: There is no significant difference of academic achievement mean score in biology in experimental and control groups on the bases of "Precision".

Table 4.20

Significance difference of academic achievement in "precision" by female groups

Intellectual Standard	Groups	Mean	Standard Deviation	Difference (t (df)= t value; P value)	Effect size (r)
Precision	Experimental	4.27	0.61	t (70)= 4.62; p < 0.001	0.48
	Control	3.36	1.01		

According to table 4.20, mean scores of the experimental and control groups for "precision" are 4.27 and 3.36 respectively having a difference of 0.91 on average. By the same token, the values of standard deviation in the experimental and control groups are 0.61 and 1.01 respectively. it indicates that score data of precision in experimental group is less spread than control group.

More over the t value is 4.62 and the level of significance is 0.000, which is less than alpha value 0.05. [t (70) = 4.62; p < 0.001; r=0.48]. The magnitude of difference was computed to calculate the effect size. So the value of effect size remained 0.48 and magnitude of the difference was medium. In this connection the results imply that there is significant difference in both the experimental and control groups in achievement of "precision". Therefore null hypothesis (H03) is rejected in female groups because there is significant difference in the achievement of "precision" in the experimental and control groups.

H04: There is no significant difference of academic achievement mean score in biology in experimental and control groups on the bases of "Relevance".

Table 4.21

Significance difference of academic achievement in "Relevance" by female groups

Intellectual Standard	Groups	Mean	Standard Deviation	Difference (t (df)= t value; P value)	Effect size (r)
Relevance	Experimental	4.44	0.65	t (70)= 8.98; p < 0.001	0.53
	Control	2.97	0.73		

The calculations of table 4.21 illustrate that mean scores of the experimental and control groups for "Relevance" are 4.44 and 2.97 respectively having a difference of 1.47 on average. Moreover, the values of standard deviation in the experimental and control groups are 0.65 and 0.73 respectively. It shows that the score data of "relevance" in experimental group is less spread out than control group.

In addition the t value is 8.98 and the level of significance is 0.000, which is less than alpha value 0.05. [t (70) = 8.98; p < 0.001; r=0.53]. The magnitude of difference was computed to calculate the effect size. So the value of effect size remained 0.53 and magnitude of the difference was large. In this connection the results imply that there is significant difference in both the experimental and control groups in achievement of "Relevance". Therefore null hypothesis (H04) is rejected in female groups because there is significant difference in the achievement of "Relevance" in the experimental and control groups.

H05: There is no significant difference of academic achievement mean score in biology in experimental and control groups on the bases of "Depth".

Table 4.22

Significance difference of academic achievement in "Depth" by female groups

Intellectual Standard	Groups	Mean	Standard Deviation	Difference (t (df)= t value; P value)	Effect size (r)
Depth	Experimental	3.94	0.95	t (70)= 12.14; p < 0.001	0.82
	Control	1.55	0.69		

According to table 4.22, mean scores of the experimental and control groups for "Depth" are 3.94 and 1.55 respectively having a difference of 2.39 on average. Moreover, the values of standard deviation in the experimental and control groups are 0.95 and 0.69 respectively. It shows that the score data of "depth" in experimental group is little less spread than control group.

In addition the t value is 12.14 and the level of significance is 0.000, which is less than alpha value 0.05. [t (70) = 12.14; p < 0.001; r=0.82]. The magnitude of difference was computed to calculate the effect size. So the value of effect size remained 0.82 and magnitude of the difference was large. In this connection the results imply that there is significant difference in both the experimental and control groups in achievement of "Depth". Therefore null hypothesis (H05) is rejected in female groups because there is significant difference in the achievement of "Depth" in the experimental and control groups.

H06: There is no significant difference of academic achievement mean score in biology in experimental and control groups on the bases of "Logic".

Table 4.23

Significance difference of academic achievement in "Logic" by female groups

Intellectual Standard	Groups	Mean	Standard Deviation	Difference (t (df)= t value; P value)	Effect size (r)
Logic	Experimental	3.80	0.78	t (70)= 19.77; p < 0.001	0.92
	Control	0.52	0.60		

According to table 4.23, mean scores of the experimental and control groups for "Logic" are 3.80 and 0.52 respectively having a difference of 3.28 on average. Moreover, the values of standard deviation in the experimental and control groups are 0.78 and 0.60 respectively. It clears the score dispersion of both groups. The score data of experimental group is more dispersed out than control group.

In addition the t value is 19.77 and the level of significance is 0.000, which is less than alpha value 0.05. [t (70) = 19.77; p < 0.001; r=0.92]. The magnitude of difference was computed to calculate the effect size. So the value of effect size remained 0.92 and magnitude of the difference was large. In this connection the results imply that there is significant difference in both the experimental and control groups in achievement of "Logic". Therefore null hypothesis (H06) is rejected in female groups because there is significant difference in the achievement of "Logic" in the experimental and control groups.

H07: There is no significant difference of academic achievement mean score in biology in experimental and control groups on the bases of "Breadth".

Table 4.24

Significance difference of academic achievement in "Breadth" by female groups

Intellectual Standard	Groups	Mean	Standard Deviation	Difference (t (df)= t value; P value)	Effect size (r)
Breadth	Experimental	3.88	0.62	t (70)= 10.15; p < 0.001	0.77
	Control	2.33	0.67		

The calculations of table 4.24 show that mean scores of the experimental and control groups for "Breadth" are 3.88 and 2.33 respectively having a difference of 1.55. Moreover, the values of standard deviation in the experimental and control groups are 0.62 and 0.67 respectively. It shows that the score data of experimental group is less spread out than control group.

In addition the t value is 10.15 and the level of significance is 0.000, which is less than alpha value 0.05. [t (70) = 10.15; p < 0.001; r=0.77]. The magnitude of difference was computed to calculate the effect size. So the value of effect size remained 0.77 and magnitude of the difference was large. In this connection the results imply that there is significant difference in both the experimental and control groups in achievement of "Breadth". Therefore null hypothesis (H07) is rejected in female groups because there is significant difference in the achievement of "Breadth" in the experimental and control groups.

H08: There is no significant difference of academic achievement mean score in biology in experimental and control groups on the bases of "Significance".

Table 4.25

Significance difference of academic achievement in "Significance" by female groups

Intellectual Standard	Groups	Mean	Standard Deviation	Difference (t (df)= t value; P value)	Effect size (r)
Significance	Experimental	3.58	0.60	t (70)= 7.78; $p < 0.001$	0.68
	Control	2.36	0.72		

The calculations of table 4.25 illustrate that mean scores of the experimental and control groups for "significance" are 3.58 and 2.36 respectively having a difference of 1.22 on average. Moreover, the values of standard deviation in the experimental and control groups are 0.60 and 0.72 respectively. It tells that the score data of "significance" in experimental group is less spread out than control group.

In addition the t value is 7.78 and the level of significance is 0.000, which is less than alpha value 0.05. [t (70) = 7.78; $p < 0.001$; r=0.68]. The magnitude of difference was computed to calculate the effect size. So the value of effect size remained 0.68 and magnitude of the difference was large. In this connection the results imply that there is significant difference in both the experimental and control groups in achievement of "significance". Therefore null hypothesis (H08) is rejected in female groups because there is significant difference in the achievement of "Significance" in the experimental and control groups.

H09: There is no significant difference of academic achievement mean score in biology in experimental and control groups on the bases of "Fairness".

Table 4.26

Significance difference of academic achievement in "Fairness" by female groups

Intellectual Standard	Groups	Mean	Standard Deviation	Difference (t (df)= t value; P value)	Effect size (r)
Fairness	Experimental	3.50	0.50	t (70)= 9.30; p < 0.001	0.55
	Control	1.97	0.84		

According to table 4.26 there are same number of students in the experimental and control groups. Mean scores of the experimental and control groups for "Fairness" are 3.50 and 1.97 respectively having a difference of 1.53 on average. Moreover, the values of standard deviation in the experimental and control groups are 0.50 and 0.84 respectively. It indicates that score data of "fairness" in control group is less spread out than control group.

In addition the t value is 9.30 and the level of significance is 0.000, which is less than alpha value 0.05. [t (70) = 9.30; p < 0.001; r=0.55]. The magnitude of difference was computed to calculate the effect size. So the value of effect size remained 0.55 and magnitude of the difference was large. In this connection the results imply that there is significant difference in both the experimental and control groups in achievement of "Fairness". Therefore null hypothesis (H09) is rejected in female groups because there is significant difference in the achievement of "Fairness" in the experimental and control groups.

Table 4.30 summarizes cell-wise values of means (M) and standard deviations (SD) for achievement scores of experimental and control groups at the girls' school. All the ability level groups have same number (12) of students. It is obvious that value of M for HAs (39.38) is greater than the values of AAs and LAs, as well the M value of AAs(36.83) is greater than LAs(34.41) taught through collaborative teaching method on the base of Paul-Elder's critical thinking model in the experimental group. This table also shows the values of M and SD for HAs, AAs and LAs in control group. In the control group the M value of AAs (25.16) is more than HAs (24.75) as well and LAs (22.25), in contrast of the experimental group.

Table 4.31
Results of ANOVA for students of female experimental and control groups

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	3210.333	5	642.067	72.604	.000
Within Groups	583.667	66	8.843		
Total	3794.000	71			

The analysis of variance in the above table 4.31 shows the comparison of six ability level groups (three from each experimental and control groups).It is clear from this table that the three groups of ability level students(HAE, AAE, LAE) taught through collaborative teaching method on the bases of Paul-Elder's critical thinking model performed significantly better as compared to the students(HAC, AAC, LAC) taught through conventional teaching method, F (5, 66) = 72.60, $p< 0.001$, SL=.05. Hence the null hypothesis H0 10 "There is no significant difference of academic achievement mean score in biology in experimental and control groups on the bases of ability levels of students." was rejected in favour of the collaborative teaching method on the bases of Paul-Elder's critical thinking model.

Table 4.32
Results of Post Hoc Tests for Multiple Comparisons of mean differences among three levels of achievement by Tukey HSD in female groups

Levels of achievement (1)	Levels of achievement (2)	Mean Difference (1)-(2)	Standard. Error of Mean (SEM)	*p*-value	Difference
HA E	AAE	2.75	1.21	0.22	Non significant
	LAE	5.16	1.21	0.001	Significant
AAE	HAE	-	-	-	Non significant
	LAE	2.41	1.21	0.35	Non significant
LAE	HAC	9.66	1.21	0.000	Significant
	AAC	9.25	1.21	0.000	Significant
HA C	AAC	-0.41	1.21	0.99	Non significant
	LAC	2.50	1.21	0.32	Non significant
AAC	HAC	-	-	-	Non significant
	LAC	2.91	1.21	0.17	Non significant

It is obvious from Turkey HSD (Honest Significant Difference) table 4.32 that the significance value for the mean differences of achievement between different ability levels (HAs, AAs, LAs) in female experimental and control groups. The entries of this table indicate the difference of mean scores as follow:

1. Table 4.32 summarizes the results of mean differences in the academic achievement found between any two categories of students out of HAs, AAs and LAs. It was found that the performance of the stated HAE is not significantly different from that of AAE ($p>0.05$, SEM = 1.66, SL=.05). It was also noted that HAE of the girls' school performed significantly different from LAE of the same school ($p< 0$ .01, SEM = 1.66, SL=.05).The results also reflected that there was no significant difference in

academic achievement of AAE from LAE. Similarly the mean difference between HAE and AAE (2.75) was noted as greater than the mean difference between AAE and LAE (2.41) in the experimental group.

2. In the multiple comparison of LAE with HAC and AAC, it was found that the performance of the stated LAE is significantly different from that of HAC ($p<0.001$, SEM = 1.66, SL=.05). It was also noted that LAE performed significantly different than AAC of the same school ($p< 0 .001$, SEM = 1.66, SL=.05).The results also reflected that there was a significant different performance of LAE from HAC and AAC. Similarly the mean difference between LAE and HAC (9.66) was noted as greater than the mean difference between LAE and AAC (9.25) in the selected girls' school.

3. The comparison of control ability groups of the girls' school shows that the performance of the stated HAC is not significantly different from that of AAC ($p>0.05$, SEM = 1.66, SL=.05). It was also noted that HAC also performed no significantly different than LAC of the same school ($p>0.05$, SEM = 1.66, SL=.05).The results also reflected that there was no significant different performance of HAC from AAC and LAC. Similarly the mean difference between HAC and AAC (-0.41) has negative sign which indicates that HAC could not perform significantly better than AAC in the girls' school.

4. The comparison analysis AAC with LAC of control ability groups indicates that the performance of the stated AAC is also not significantly different from that of LAC ($p>0.05$, SEM = 1.66, SL=.05). The results also reflected that there was no significant different performance of AAC from LAC. In addition the mean difference between AAC and LAC (2.91) was noted as greater than the mean difference between HAC and LAC (2.50) in the selected girls' school.

Chapter No.5

Summary, Findings, Discussion, Conclusions and Recommendations

5.1 Summary

This study was conducted to determine the effectiveness of the critical thinking model by comparing the collaborative and conventional teaching methods in biology at the secondary level. Three units (17, 18, and 19) were included from the biology textbook of class 10 for this experimental study. The textbook was published by Balochistan Text Book Board in 2018. The researcher developed 36 lesson plans from these three units to treat the experimental and control groups. Expert opinions were also taken to develop the lesson plans. Students' Achievement Test (SAT) as the research instrument was developed by the researcher based on nine intellectual standards of Paul-Elder's critical thinking model through the table of specification. It was applied before and after the intervention as the pre-test and the post-test respectively. Moreover, pilot testing was conducted for the reliability of the research instrument and criterion validity of the standardized Critical Thinking Test (CTT). The split-half method was applied for the reliability of the research instrument.

All the secondary level science students in Balochistan were considered as the target population of the study. The Researcher selected two government high schools (boys and girls) in Quetta city as an accessible population to conduct the experiment of the study. On the base of the convenience of the researcher, both schools were selected from satellite town Quetta. Sample size of the study was consisted of 72 students in each school selected through simple random sampling and overall sample size of both the schools was consisted of 144 students (72 boys &72 girls). The researcher divided the sample of one school into two equal experimental and control

groups through pairing technique with the help of Annual Examination Scores (AES). Each group was further divided equally at ability levels. The abilities were categorised in to higher achievers, average achievers and lower achievers to determine the abilities of critical thinking among the students. The base line of the students in biology was checked by Pre-test. Both the experimental groups (boys and girls) were treated by the researcher through collaborative teaching method. But the control group was taught by their school teachers through conventional teaching method.

Factorial design (2x3) was applied due to more than one independent variable. Teaching methods and ability levels of students are two independent variables. These variables are called the factors: the teaching method is considered as factor A and ability level of academic achievement is factor B. After the last session of intervention, the same pre-test was administered as the post-test. The duration of the experiment remained two months with effect from September 23, 2019, to November 21, 2019.

After collecting data of the post-test, the data were analyzed through SPSS (V.20). The researcher applied dependent t-test to compare the achievement of students of the same group in pre-test and post-test. Another inferential statistic test was used called the independent sample t-test, which is a statistical test to compare the achievements of experimental and control groups and to determine the significant difference in both groups. Effect size was also calculated to determine the magnitude of difference in academic achievement of both groups. Similarly, the significant difference in academic achievement in the three ability levels was calculated by the application of analysis of variance (ANOVA) to find out the effectiveness of Paul-Elder's critical thinking model in different ability levels of students. The above-

mentioned tests were applied with the help of SPSS (V.20). Based on the analysis of data, the findings of the study were obtained.

5.2 Findings of the Study

The findings of the study were drawn from the analysis of the data.

1. Basic abilities of critical thinking and concepts of the biology of male experimental and control groups were determined before the treatment. From the result, it was found that there was a minor difference in mean scores (0.11) of experimental and control groups because the mean scores of pre-test in the experimental and control groups were 4.77 and 4.66 respectively (Table 4.1), in addition, the inferential analysis in the same table confirms the comparison of both groups and declared that there was no significant difference between the experimental and control groups before the treatment. The p-value (0.73) is greater than the alpha value 0.05($p>0.05$).

Basic abilities of critical thinking and concepts of the biology of female experimental and control groups were determined before the treatment. From the result, it was found that there was a minor difference in mean scores between both the groups because the mean scores of pre-test in the experimental and control group were 4.64 and 4.63 respectively. In addition, inferential analysis confirms the comparison of both groups and declared that there was no significant difference between the experimental group and the control group before the treatment. The p-value (0.93) is greater than the alpha value 0.05($p>0.05$). (Table 4.2)

2. To determine the effect of critical thinking on students' academic achievement in biology at secondary level through collaborative teaching method based on Paul-Elder's critical thinking model (objective 1). Through the analysis, it was found that the experimental group (male) achieved significantly better in the post-test as compared to the pre-test. Moreover, the correlation of 36 students appears positive

(0.59) which proves the achievement in the post-test. In this continuation, there was found a significant difference in the scores of pre-test and post-test (Table 4.3).

From the interpretation of table 4.5, it was found that the difference of scores exists before and after the treatments in the female experimental group. The mean score difference (32.28) of the female experimental group showed that the experimental group (female) improved after the treatment. Additionally, the correlation of 36 candidates score was 0.20 which is a positive correlation increasing the achievements of the sample before and after the treatment. The significant difference indicated that female students of the experimental group achieved significantly better in the post-test. It was found that critical thinking skill at secondary level can be developed by applying the intellectual standards of Paul-Elder's critical thinking model in the class room.

3. Objective No.2 of the study is to find out the effect of critical thinking on students' academic achievement in biology at the secondary level through the conventional teaching method. It was found that the achievement scores through conventional teaching methods in control groups indicated the difference of scores before and after the treatments in male and female control groups. The findings of table 4.4 indicated the difference in scores before and after the treatments in the male control group. The difference in mean scores (19.39) indicated that the male control group also improved after the treatment. Additionally, the correlation of 36 candidates score was 0.12 which is a positive correlation increasing the achievements of the sample before and after the treatment. The significant difference in the scores of the pre-test and the post-test confirms that students achieved significantly in the post-test.

Table 4.6 indicated the difference in scores before and after the treatments in the female control group. In addition, 19.42 is the mean score difference between pre-

test and post-test in the female control group showed that the control group (female) improved after the treatment. Additionally, the correlation of 36 candidates score was -.032 which is a negative correlation but increasing the achievements of the sample in post-test because it is a very less negative value. It was found a significant difference in the pre-test and post-test of the female control group.

4. To compare the effect of critical thinking in biology based on collaborative and conventional teaching methods on academic achievement of students at the secondary level (objective 3), it was found that the significant academic achievement difference in the experimental and control group was found after intervention through collaborative and conventional teaching methods respectively. The descriptive and inferential statistical analysis of post-test scores in male experimental and control group found the mean score difference which is 10.72 and p-value (0.00) is less than 0.5 which indicates that there is a significant difference in the academic achievement of male experimental and control group. In addition, the effect size of difference was calculated between the mean scores of the experimental and control groups to measure the magnitude of significant difference. It was found that the magnitude of the difference was large. (Table 4.7)

At the same time, table 4.8 showed that as like the male groups, the female experimental and control groups has a significant difference in the academic achievement in post-test due to the less p-value (0.00) than the alpha value and the magnitude of effect size remained large. For this reason, it was found that the collaborative teaching method based on the application of intellectual standards of Paul-Elder's critical thinking model gives significantly better results in the development of critical thinking in science students at the secondary level than the conventional teaching method.

5. After the intervention, most of the intellectual standards of Paul-Elder's critical thinking model have a significant difference in experimental and control groups. Findings of the statistical descriptive and inferential analysis of the post-test data accepted or rejected the hypotheses of the study as follow:

i) The achievement difference based on "Clarity" between male experimental and control group was found that students of experimental groups were performing somewhat better than the control group but there was no significant difference of both male groups in the achievement of first intellectual standard "Clarity". Similarly female experimental and control groups have no significant difference in the academic achievement of "Clarity". It was also found that the magnitude of effect size in male and female groups remained small (table 4.9, 4.18). It was found that the null hypothesis (H01) was accepted in both male and female groups because there was no significant difference in the academic achievement based on "Clarity" in biology.

ii) The achievement difference based on "Accuracy" between male experimental and control groups was found that students of experimental groups were performing somewhat better than the control group but there was no significant difference of male experimental and control groups in the achievement of second intellectual standard "Accuracy" because the *p*-value (0.60) is greater than the alpha value(0.05) and the magnitude of effect size was small. In contrast, female experimental and control groups have a significant difference in the academic achievement of "Accuracy" because the *p*-value (0.023) is less than the alpha value 0.05 even the magnitude of effect size remained small (table 4.10, 4.19). It was found that the null hypothesis (H02) was accepted in male experimental and control groups because there was no significant difference in the academic achievement based on "Accuracy" in biology. On the other hand, the null hypothesis (H02) was rejected in female experimental and

control groups because the significant difference was present based on "Accuracy" in biology.

iii) Achievement difference based on "Precision" between students of male experimental and control groups in post-test indicated that the scores of the male experimental group performing better (M= M=3.97, SD=0.69) than the male control group (M=3.30, SD=0.82) (Table 4.11), in addition, the inferential analysis inferred that the achievement scores have significant difference based on "Precision" after the instructions due to the p-value (0.00) is less than the alpha value 0.05 and the magnitude of effect size was calculated as the medium.

Similarly, achievement scores difference on the base of "Precision" in post-test found that that female Experimental group performing better (M=4.27, SD=0.61) than the female control group (M=3.37, SD=1.01) after the instruction (Table 4.20). Moreover, inferential analysis inferred that the achievement scores have a significant difference based on "Precision" after the instructions due to the less p-value (0.00) than the alpha value 0.05. In addition, the effect size remained medium. It was found that the null hypothesis (H03) was rejected due to a significant difference in the mean scores of experimental and control groups based on "Precision" in biology.

iv. Achievement difference based on "Relevance" between students of male experimental and control groups in post-test indicated that the scores of the male experimental group performing better (M=3.72, SD=0.77) than the male control group (M=2.27, SD=0.94) (Table4.12), and inferential analysis inferred that the achievement scores have significant difference based on "Relevance" after the instructions because the *p*-value (0.00) is less than the alpha value 0.05. Moreover, the magnitude of the effect size was count to be large.

Similarly, achievement scores difference based on "Accuracy" in post-test found that the female experimental group performing better (M=4.44, SD=0.65) than the female control group (M=2.97, SD=0.73) after the instruction (Table 4.21). Moreover, inferential analysis inferred that the achievement scores have a significant difference based on "Accuracy" after the instructions having p-value (0.00) less than the alpha value 0.05. In addition, the effect size remained large. It was found that the null hypothesis (H04) was rejected due to a significant difference in the mean scores of experimental and control groups based on "Accuracy" in biology.

v. Achievement difference based on "Depth" between students of male experimental and control groups in post-test indicated that the scores of the male experimental group performing better (M=3.94, SD=0.95) than the male control group (M=1.55, SD=0.69) (Table 4.13), in addition, inferential analysis inferred that the achievement scores have significant difference based on "Depth" after the instructions due to having less *p*-value(0.00) than the alpha value 0.05 and the magnitude of the difference was calculated large.

Similarly, achievement scores difference on the base of "Depth" in post-test found that that female Experimental group performing better (M=3.94, SD=0.95) than the female control group (M=1.55, SD=0.69) after the instruction (Table 4.22). Moreover, inferential analysis inferred that the achievement scores have a significant difference based on "Depth" after the instructions due to the less p-value (0.00) than the alpha value 0.05, and the magnitude of the difference remained large. It was found that the null hypothesis (H05) was rejected due to a significant difference in the mean scores of experimental and control groups based on "Depth" in biology.

vi) Achievement difference based on "Logic" between students of male experimental and control group in post-test indicated that the students of the male experimental

group performing better (M=3.80, SD=0.78) than the male control group (M=0.52, SD=0.60) (Table4.14), and inferential analysis clears that the achievement scores have significant difference based on "Logic" after the instructions due to the *p*-value (0.00) less than the alpha value 0.05 and the magnitude of difference remained large.

Similarly, achievement scores difference based on "Logic" in post-test found that that female Experimental group performing better (M=3.80, SD=0.78) than the female control group (M=0.52, SD=0.60) after the instruction (Table 4.23). Moreover, inferential analysis inferred that the achievement scores have a significant difference based on "Logic" after the instructions due to the less p-value (0.00) than the alpha value 0.05 and the magnitude of the effect size was large. It was found that the null hypothesis (H06) was rejected due to a significant difference in the mean scores of experimental and control groups based on "Logic" in biology.

vii) Achievement difference based on "Breadth" between students of male experimental and control group in post-test indicated that the scores of the male experimental group performing better (M=3.72, SD=0.56) than the male control group (M=2.33, SD=0.71) (Table 4.15), so it was found from the inferential analysis that the achievement scores have significant difference based on "Breadth" after the instructions due to the less *p*-value (0.00) than the alpha value 0.05 and having large effect size.

Similarly, achievement scores difference on the base of "Breadth" in post-test found that that female Experimental group performing better (M=3.88, SD=0.62) than the female control group (M=2.33, SD=0.67) after the instruction (Table 4.24). Moreover, inferential analysis inferred that the achievement scores have a significant difference based on "Breadth" after the instructions due to the less p-value (0.00) than the alpha value 0.05 and the effect size remained large. It was found that the null

hypothesis (H07) was rejected due to a significant difference in the mean scores of experimental and control groups based on "Breadth" in biology.

viii) Achievement difference based on "Significance" between students of male experimental and control group in post-test indicated that the scores of male Experimental group performing better (M=4.02, SD=0.69) than the male control group (M=2.25, SD=0.64 (Table 4.16), inferential analysis clears that the achievement scores have significant difference based on "Significance" after the instructions due to the less *p*-value (0.00) than the alpha value 0.05 and the magnitude of effect size is large.

Similarly, achievement scores difference on the base of "Significance" in post-test found that that female Experimental group performing better (M=3.58, SD=0.60) than the female control group(M=2.36, SD=0.72) after the instruction(Table 4.25). Moreover, inferential analysis inferred that the achievement scores have a significant difference based on "Significance" after the instructions due to the less p-value(0.00) than the alpha value 0.05 and the value of effect size remained large. It was found that the null hypothesis (H08) was rejected due to a significant difference in the mean scores of experimental and control groups based on "Significance" in biology.

ix) Achievement difference based on "Fairness" between students of male experimental and control groups in post-test indicated that the scores of the male experimental group performing better (M=4.02, SD=0.69) than the male control group (M=2.25, SD=0.76) (Table4.17), in addition, inferential analysis inferred that the achievement scores have significant difference based on "Fairness" after the instructions due to the less *p*-value(0.00) than the alpha value 0.05 and the magnitude of effect size remained large.

Similarly, achievement scores difference on the base of "Fairness" in post-test found that that female Experimental group performing better (M=3.50, SD=0.50) than the female control group(M=1.97, SD=0.84) after the instruction(Table 4.26). Moreover, inferential analysis inferred that the achievement scores have a significant difference based on "Fairness" after the instructions due to the less *p*-value (0.00) than the alpha value 0.05 and the effect size was large. It was found that the null hypothesis (H09) was rejected due to a significant difference in the mean scores of experimental and control groups based on "Fairness" in biology.

6. It was found from the analysis of variance (ANOVA) that there is a significant difference in the academic achievement of the experimental and control groups based on ability level. It also inferred the multiple comparisons at ability levels (HAE, AAE, LAE, HAC, AAC, and LAC) after the treatment as follows (tab 4.27-4.29). HAE in the male experimental group has a significant improvement among all the ability levels of both groups. AAE and LAE also achieved significantly better than all ability levels of the control group. Similarly, HAC, AAC, and LAC in the male control group have a significant difference among all the ability levels of experimental groups but there is no significant difference of ability levels in the same control group after the treatment. It was found that the three groups of ability level students (HAE, AAE, LAE) taught through collaborative teaching method based on Paul-Elder's critical thinking model performed significantly better as compared to the students (HAC, AAC, LAC) taught through the conventional teaching method. Hence the null hypothesis H0 10 "There is no significant difference of academic achievement mean score in biology in experimental and control groups based on ability levels of students." was rejected in favour of the collaborative teaching method based on Paul-Elder's critical thinking model.

7. It was found from the analysis of variance (ANOVA) that there is a significant difference in the academic achievements of female experimental and control groups based on ability level. It also inferred the multiple comparisons at ability levels (HAE, AAE, LAE, HAC, AAC, and LAC) after the treatment as follow (tab 4.30-4.32). HAE in the female experimental group has a significant improvement among all the ability levels of both groups. AAE and LAE also achieved significantly better than all ability levels of the control group. Similarly, HAC, AAC, and LAC in the female control group have a significant difference among all the ability levels of experimental groups but there is no significant difference of ability levels in the same control group after the treatment. It was found that the three groups of ability-level female students (HAE, AAE, LAE) taught through collaborative teaching method based on Paul-Elder's critical thinking model performed significantly better as compared to the students(HAC, AAC, LAC) taught through the conventional teaching method. Hence the null hypothesis H0 10 "There is no significant difference of academic achievement mean score in biology in experimental and control groups based on ability levels of students." was rejected in favor of the collaborative teaching method based on Paul-Elder's critical thinking model.

5.3 Discussion

This experimental research study was conducted to find out the effectiveness of Paul-Elder's critical thinking model through collaborative teaching method in the experimental group and compared with the control group. The researcher selected the biology subject for the study at the secondary level in Balochistan. The study was based upon three objectives which were to determine, to find out, and to compare the effectiveness of critical thinking in biology based on Collaborative and Conventional Teaching Methods on academic achievement of students at the secondary level. For

this purpose, the biology subject of class 10 was selected for the intervention. Through the pre-test of male and female students, it was confirmed that both the experimental and control groups were the same but after the application of intellectual standards of Paul-Elder's critical thinking model through collaborative teaching method in experimental groups at the secondary level, the significant difference acquired in the scores of academic achievement in biology. This result confirms the previous study conducted by Jun Xu (2011) who concluded that the experimental group of students at the secondary level performed significantly better than the control group due to the application of Paul-Elder's critical thinking model on developing critical thinking in the students at the secondary level.

According to Paul and Elder (2005, 2008, 2013), the collaborative teaching method develops the abilities of critical thinking in the students. The findings of the present study verify the research conducted in past to test the effect of Paul-Elder's critical thinking model. Khan and Mahmood (2017) concluded that students promote their critical skills and new information through the use of Paul-Elder's critical thinking model. As stated by Khan and Muhammad (2017), the findings of their studies were also supported by Kitsantas et al (2019), Florea & Hurjui (2015).In addition, differentiating the normal thinking and critical thinking by Lipman (1988) that the students of the experimental group have precise and accurate thinking in biology than the control group and also proved the suggestions of Paul&Elder (2005) that first identify the strengths and weaknesses of thinking and secondly reshape it in an improved form. But the control group through the conventional method could not show a significant ability of critical thinking.

Critical thinking is a cognitive skill stated by American Philosophical Association Delphi Report (1990), the present study results also support this point.

Critical thinking as a cognitive skill was supported by Franco and Almeida (2011), Ornstein and Hunkins (2004), Brookfield (2012), Pascarella and Terenzini (2005). Dewi (2004), Ennis (1992) called critical thinking is the reflective thinking developed through questioning and active learning. In this study, the Socratic questioning method was applied for the promotion of critical thinking in the experimental group which verifies the model of John Dewi. Bollom (1956) considered higher-level thinking (analysis, synthesis, and evaluation) as critical thinking. Intellectual standards as the component of Paul-Elder's critical thinking model can analyze and evaluate the information in the "depth" and "logic" that favours the Bloom taxonomy. According to Delphi's report (1990), critical thinking is the ability of interpretation, analysis, evaluation, inferences, and judgment. The intellectual standards of Paul-Elder's critical thinking model consist of nine standards: Clarity, Accuracy, Precision, Relevance, Depth, Logic, Breadth, Significance, and Fairness. These standards focus on all the steps of the Delphi report. According to Matheo Lipman (2003), critical thinking should be sensitive to context and cannot be generalized. In contrast to his point of view Paul-Elder's critical thinking is not context-based; in this study, the application of intellectual standards developed the critical thinking in students of Balochistan (province of Pakistan) at the secondary level, which proves that critical thinking is not context-based. According to Paul and Elder (2008) if the intellectual standards are applied to the elements of thoughts, then critical thinking can be produced in the students. Discussing the elements of thoughts Paul and Elder explained that "whenever we think, we think for a purpose within a point of view based on assumptions leading to implications and inferences and we use information based on a concept to answer the questions to resolve the issue. The researcher described the elements of thoughts in this study as follows: the purpose of thoughts

was the objectives of study having the point of view based on the assumptions which were the nine hypotheses of this study. The implication of the experiment was done based on these hypotheses and inferences were concluded. The issue of this study is to find out the effect of this model on the academic achievement of critical thinking was resolved based on information which answered the question that how critical thinking can be developed in the students? According to Coughlin (2010) Students at the secondary level must aware of the use of techniques to learn, innovate, media and technology. And he found that in the subject matters, the success of students is more related to critical thinking than traditional. The findings of this study prove the above statements because the application of intellectual standards makes able the students that how to learn.

Critical thinking skills improved academic achievement suggested by Paul & Elder, 2008, Srijith (2019), Paul and Elder (2009), and Coughlin (2010). This study proved that critical thinking skills improved academic achievement in boys as well as girls students. Instructional strategies for critical thinking show that asking questions (Paul & Elder,2003), active participation of the students(Maiorana,1992), the attitude of teacher affect the critical thinking (Paul, 1995), Socratic lecture/discussion as the main way of teaching with a strong association to student perceptions of critical thinking (Carlson, 2013), the problem-solving teaching-learning process enhance critical thinking in their content area (McCollister and Sayler, 2010), the best critical thinking teaching applies a gradual enhancement (scaffolding method) from simple to complex (Wertz, 2019). Cvetkovic and Stanojevic (2017), Asyari et al.(2016) favored the collaborative teaching method to promote the abilities of critical thinking in the learning of students. The results of the present study support the ideas of scholars about instructional strategies and critical thinking. In this study the researcher applied

the Socratic discussion method to avoid passiveness, attitude of the researcher maintained the learning environment friendly. Scaffolding is the key method for the teachers to teach the students. The brainstorming technique was used to understand the levels of the students to move forward. Think pair share strategy was applied as a collaborative method of teaching to develop the abilities of critical thinking. When we discuss and compare the academic achievement of students at ability levels in both groups then the scores of high achievers in the experimental group have learned better than the lower achievers. It proves the effectiveness of Paul-Elder's critical thinking model. On the other side in the control group, the intellectual standards were controlled; therefore no significant change of critical thinking was appeared but only improved as compared to the scores of the pre-test. In addition, Average achievers and lower achievers in the experimental groups achieved better than all the ability levels of the control group. These results prove that experimental groups achieved better than the control group in the achievement of critical thinking. The reason may be the control of intellectual standards in the students of the control group who did not have a critical level of thinking in which they could plan and assess their study which may be unsystematic. It also shows that the lower achievers in the experimental groups were also fully involved in the learning through a collaborative method like think pair share and Socratic discussion.

It was declared from the findings of the study that there was a significant change in both groups in academic achievement. The clarity which is the first and basic intellectual standard of Paul-Elder's critical thinking model has no significant difference in both groups. The reason is that clarity belongs to the basic conceptual knowledge of the content. The students who belong to control groups have learned the basic concepts through conventional teaching methods as well. The second intellectual

standard of Paul-Elder's critical thinking model is accuracy which is also having no depth and logic, therefore, no significant difference was found in the male experimental and control groups but in female groups, the significant difference exists. In addition, intellectual standards of academic achievement have a significant difference in both groups. According to Lee Watanabe Crockett (2019) egocentric thinking, stereotyping and personal biases are the main barriers to think critically. The finding of the study revealed that the barrier of egocentric, stereotyping concepts, and personal biases were been controlled to develop critical thinking.

Dewey (1910) suggests that the barriers are classified into two categories which are intrinsic and extrinsic. One of the intrinsic is temperament and the extrinsic proceeds from generic social conditions. The critical thinking ability of the researcher must have a temperament and should control the barrier from the environment. Ozkan-Akan (2003) indicated the lack of time is the barrier to improve critical thinking. Findings of the study indicated that within a limited time of two months, three chapters of Biology were covered through Paul- Elder critical thinking model, so this issue can be resolved through proper planning of instruction. In this study, the students of the experimental group faced some difficulties like generating questions and raising questions during Socratic Discussion. They were hesitating to ask questions but the motivation and encouraging environment through researcher make them active to involve themselves to analyze and to make a decision confidently. After reviewing the related research, it was revealed that science students at the secondary level in the experimental group develop critical thinking through the application of critical thinking and achieve better than conventional teaching methods.

5.4 Conclusions

The findings of the study have been concluded as follow:

1. Application of the intellectual standards of Paul-Elder's critical thinking model through collaborative teaching method in experimental groups has a positive effect as compared to control groups in the academic achievement of science students to teach biology at secondary level in Balochistan due to analyzing, inferring, and solving the problem based on Clarity, Accuracy, Precision, Relevance, Depth, Logic, Breadth, Significance and Fairness.
2. "Clarity" is the first intellectual standard in the Paul-Elder's critical thinking model, which tells us to be clear about the subject or topic having no vagueness and confusion. The students of biology in Balochistan at secondary level in the experimental and control groups have no significant difference in the achievement scores at both boys' and girls' schools. It was concluded that students have no ambiguity about the basic concepts of biology taught through collaborative and conventional teaching methods.
3. "Accuracy" is the content or information free from errors, which is one of the intellectual standards of Paul-Elder's critical thinking model. It is inferred that control group (male) at secondary level in Balochistan which was treated through the conventional teaching method has no significant difference with the experimental group because the content accuracy level in control group was significantly same with the experimental group. It was the hard work of school teacher who taught the control group through conventional method. However, the control group in female students found a significant difference in the achievement of "accuracy". It shows that female students in experimental group achieved good scores than control group and students of control group has significantly less accuracy level than the experimental group.

4. Subsequently, the intellectual standard "Precision" was concluded in such a way that precision is the specification of the concept or exact to the necessary level of detail. The students must specify and precise their thinking about the information. The students who were taught by applying the intellectual standard in the experimental groups achieve a significant improvement in "precision" than the control groups taught through the conventional lecture method in Balochistan at the secondary level.
5. Another important aspect of the intellectual standard is "Relevance" which deals with the relevant information of the topic. The results of the "Relevance" remained effective equally for all the ability levels in the experimental groups of male and female students unlike the conventional teaching method in the students of control groups. Furthermore, it is concluded that the higher achievers focus the relevant information to solve the problem, or this standard helps them to make the right decision.
6. "Depth" is the key component of the intellectual standards which indicates the thinking complexity or multiple interrelationship of the concept. Usually, students feel difficulty at the analysis level of the concept but in this study at the secondary level in Balochistan, it was concluded that the students in male and female groups who were taught through applying the intellectual standard the "depth", thought in-depth to analyze the different aspects of the concept to make a good decision.
7. "Breadth" encircles the multiple view points of the information or problem. It is concluded that students of experimental groups significantly performed better than control group having a skill of breadth. They thought out of the box to solve the problem.

8. "Logic" is one of the intellectual standards in Paul-Elder's critical thinking model that provides evidence and reasoning of the information. It is concluded that the students who are taught through intellectual standards including "logic" can be able to develop reasons for the information and make a good decision. In contrast, with the students in control, groups could not perform better during learning.
9. Another important intellectual standard is "Significance" which focuses on the most important facts and central idea of the information. It is concluded that though picking the central idea of the concept, the students can achieve the main concept and perform better. In this study in Balochistan at the secondary level, the experimental groups performed better due to getting the "significance" of the topic. Students can understand the importance of significance through think-pair-share and inquiry methods of teaching which focus the central idea of the topic by discussion.
10. "Fairness" is justifiable thinking in the context. It is concluded that the students who can justify the learning according to the context, that helps them to make their decision correct. The students in the male and female experimental groups practiced to justify the questions, developed the skill of fairness which helped them to make the right decision, and performed better than the control groups.
11. Through the analysis of variance, it was concluded that all the ability levels of experimental groups (HAE, AAE, LAE) achieved better significantly than the ability levels of control groups (HAC, AAC, LAC) in biology at the secondary level in Balochistan. High achievement of experimental groups is due to the application of intellectual standards of Paul-Elder's critical thinking model

through the interactive learning environment, think pair share, inquiry method, and immediate feedback of teacher (the researcher) during teaching as well as on assignments. It was concluded that science students at the secondary level in Balochistan performed better in their academic achievement by applying Paul-Elder's critical thinking model through the collaborative teaching method.

5.5 Recommendations

The conclusions of this experimental study illustrate that students of experimental and control groups had the same academic ability before the intervention but after the treatment, a significant difference was found in the academic achievement of both the groups. It proves that Paul-Elder's critical thinking model develops critical thinking in students through the application of the collaborative teaching method. Henceforth, it has been proved that Paul-Elder's critical thinking model is a useful model which helps the students to enhance their academic achievement to reach their highest level of learning. It is also proved that this model is also positively effective in the development of critical thinking and learning of biology at the secondary level. The recommendations are specified in such a way that: first for teachers, second for students, and third for curriculum designers. In the end, the scope for future research is recommended.

5.5.1 Recommendations for teachers.

The best teaching and learning occurs through cooperation, not in a passive way. Teachers must learn critical thinking skills to teach the students according to these skills. The present study proved that the students who were taught under the consideration of Paul Elder's critical thinking model performed better than the

students who did not use this model. In the light of this conclusion, it is recommended that:

1. Teachers at the secondary level may be equipped with critical thinking skills to apply these skills in the classroom. Moreover, it is recommended that the content of Paul-Elder's critical thinking model may be included in the pre-service as well as in-service teachers' training programs by Provincial Institute for Teacher Education (PITE) Balochistan.
2. Cooperative teaching method is the learner-centred approach which is useful to create critical thinking in the students. It is recommended to apply cooperative learning strategies by biology teachers in the classrooms at secondary level to develop critical thinking.
3. Teachers must create such an environment in which the students may question freely, involve in divergent thinking, remained active both physically and cognitively, solve their academic and social issues due to divergent thinking and good decision making.

5.5.2 Recommendations for students.

The students must think critically in science subjects to solve academic problems and to achieve the highest level of learning. It means that they must participate actively in the learning and problem-solving process. Therefore they are recommended:

1. Students should learn about the application of intellectual standards of Paul-Elders' critical thinking model for the deep learning of subject matter and decision making in everyday life.

2. Critical thinkers ask proper questions, answer the questions with reasoning and sum up the reliable conclusion to solve any problem. Students may develop the skills of critical thinking by practicing Paul-Elder's critical thinking model because

3. Deep learning cannot occur passively. Students should participate actively in the classroom through discussion, questioning, and reasoning for meaningful learning.

4. It is recommended to all types of ability level students that they may apply Paul-Elder's critical thinking model whether they are high achievers, average achievers, or low achievers for the development of critical thinking. Extrinsic motivation from teachers and parents can motivate the students for self regulation and critical thinking.

5.5.3 Recommendations for curriculum developers.

The basic aim of education is to produce educated and sensible citizens in society. Poor academic learning produce an uncivilized society which shows that there is something wrong in the education. So curriculum developers and text book writers may solve such types of problems. The conclusions of this study recommend as follow to reduce this issue through the introduction of the Paul-Elder critical thinking model in the curriculum and text book.

1. There is a need to transform the textbook of "Biology" in collaborative instructional strategy having intellectual standards instead of lecture based instructional strategy. So a committee of experts may be appointed to prepare the textbook for teaching biology at secondary level.

2. The assessment exercises in the textbooks must reflect all the nine intellectual standards of critical thinking that will develop the critical thinking of the learners that

will affect the educational achievement of the students. Such type of recommendations can be achieved through professional development of curriculum developers and text book writers by Bureau of Curriculum and Extension Centre, Balochistan.

3. To avoid the replication of knowledge in the annual exams at the secondary level, it is the responsibility of Balochistan Board of Intermediate and Secondary Education to train the paper setters for this model to assess the deep understanding of the students.

5.5.4 Recommendations for future researchers.

This study concluded that Paul-Elder's critical thinking model improves the academic achievement of students in biology at the secondary level. This study may give new scope for new research. Recommendations for future researchers are given as follow:

1. The same study having a different population may be repeated to verify the findings of the present study.
2. This research study was done on biology at the secondary level to determine the effect of Paul Elder's critical thinking model. This model may be investigated in other subjects of science, arts, or humanities at the same or different levels.
3. For deeper analysis, qualitative research may be carried out to explore the effectiveness of Paul-Elder's critical thinking model.
4. Paul-Elder's critical thinking model may be investigated in schools of the private sector. Achievements through applying Paul-Elder's critical thinking model can be compared in urban and rural areas.

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APPENDICES

Appendix 1

Lesson Plan No.1 (Experimental Group)

Date Sept 23, 2019
Class 10^{th}
Period 40 minutes
Subject Biology
Topic Heredity, Genes and their role in Biological inheritance

General objectives	The general objectives of this lesson will be to: 1) Organize collaborative instructional strategies for the students to create an enriched environment consistent with the Paul-Elder Intellectual standards of critical thinking. 2) Develop "low threat and high challenge" environment among learners studying at secondary level. 3)Minimize the role of rote-learning and maximize benefiting from critical thinking standards for inculcation of biological concepts.
Specific objectives	After going through this lesson , the students will be able to: Unde 1) understand and elaborate the concepts with examples related to heredity and gene. 2) analyze the importance of gene in daily life. 3) Justify the concepts of heredity in human.□
Material	Text books, Handouts, White Board Marker
Introduction **Brain Storming** (03 minutes)	Teacher will ask questions from the students about the inheritance. What is heredity? Why does your colour of eyes match with your parents? What is gene?

<table>
<tr><td>Statement of aim (Announcement of topic) (01 minute)</td><td colspan="2">Heredity, Genes and their role in Biological inheritance</td></tr>
<tr><td>Presentation
(20 minutes)</td><td colspan="2">Inquiry Method: Teacher will allow students to open books to read for ten minutes individually, then teacher will distribute the questions to discuss in pairs and give answers. Teacher will ask following questions as a reflection to check critical thinking. Same questions will be assigned for home work assignment.</td></tr>
<tr><td></td><td>Instructional strategies</td><td>Developing Critical thinking through intellectual standards</td></tr>
<tr><td></td><td>What is gene and heredity? Give two examples of heredity from the daily life?</td><td>Clarity, Accuracy, Precision & Relevance</td></tr>
<tr><td></td><td>What is the relationship of gene and chromosome?</td><td>Depth</td></tr>
<tr><td></td><td>Are the genes present in all living organisms?</td><td>Breadth</td></tr>
<tr><td></td><td>How genes transfer from parents to offspring?</td><td>Logic:</td></tr>
<tr><td></td><td>What is the importance of gene in our life?</td><td>Significance</td></tr>
<tr><td></td><td>Why human is called diploid organism?</td><td>Fairness</td></tr>
</table>

Explanation Teacher will ask and explain the answer of students by giving specific examples of heredity from the daily life. (10 minutes)	**Clarity & Accuracy**: heredity is the transfer of characteristics from parents to offspring. The resemblance of shape with your parents is the heredity. Genes control these characteristics. **Precision & Relevance:** Resemblance of your colour of eyes with your father, mother or forefathers and the resemblance of colour of hairs or height is the heredity. **Depth & Breadth:** Genes are the part of chromosomes and present in all living organisms. **Logic:** Genes transfer to the offspring through gametes. **Significance:** Genes are responsible to give the shape of an organism. **Fairness:** Chromosomes in the cells of human are arranged in pairs, so called diploid.
Review Questions . The purpose of these questions is to practice the student's learning (05 minutes)	What is heredity? What is the function of gene? How genes and chromosomes are different? How genes transfer from parents to the offspring?
Home assignment At the end of the lesson, home assignment is given to the students on the same teaching unit. (01minute)	Write the answers of the questions which are provided you.

Lesson Plan No.1 (Control Group)

Date Sept 23, 2019
Class 10^{th}
Period 40 minutes
Subject Biology
Topic Heredity, Genes and their role in Biological inheritance

General objectives	The general objectives of this lesson will be to: 1) Organize conventional instructional strategies for the students to reproduce the concepts present in text book. 2) Develop a passive environment among learners studying at secondary level. 3) Maximize the role of rote-learning and control benefiting from critical thinking standards for inculcation of biological concepts.
Specific objectives	After going through this lesson , the students will be able to: 1) Memorise the concepts related to heredity and gene. 2) Understand the concept of heredity and gene.
Material	Text books, Handouts, White Board Marker
Introduction (03 minutes)	Teacher will ask the students to open the books and page number. Allow the students to note the main points during lecture.
Statement of aim (Announcement of topic) (01 minute)	Heredity, Genes and their role in Biological inheritance
Presentation (20 minutes)	**Lecture Method.** Teacher will ask students to open Biology textbook at page

	No. 134 where topic is given. Teacher will explain all the same by writing the main points on the white board. He will also perform following activities.
Explanation Teacher will explain the terms given in the text book (10 minutes)	Asking forcibly all students to copy one by one all concepts written on whiteboard □□Explanation with the help of some examples and students writing them on whiteboard □□Showing resentment/anger/displeasure on a) poor attention b) copying slowly/ imperfectly/ differently c) talking/laughing with one another d) making mistakes e) questioning during teaching or writing sessions f) Seeking permission to have water during teaching session by the students. Teacher will ask all students to give a tight look to above the terms within 5 minutes. After 5 minutes, teacher will order all class to be attentive to note down the question given in textbook. Teacher will revise and explain most of the terms given in textbook at page No. 134-136. At the end, teacher will assign students to reproduce classroom tasks in written form on notebooks.

Review Questions The purpose of these questions is to practice the student's learning (05 minutes)	What is heredity? What is the function of gene? How genes transfer from parents to the offspring?
Home assignment At the end of the lesson, home assignment is given to the students on the same teaching unit. (01minute)	Write the answers of this topic in your note books .

Pre-Test Post Test

EFFECT OF PAUL-ELDER CRITICAL THINKING MODEL ON THE ACADEMIC ACHIEVEMENTOF SCIENCE STUDENTS AT SECONDARY LEVEL IN BALOCHISTAN

Name of student---------- Name of school----------
Total marks: 46
Time: 1 h 10 minutes

Subject Biology
Units Genes and Inheritance, Evolution and Environmental Biology
Class 10th

Multiple Choice Questions (MCQs)

Note: Each question is followed by four options. Encircle the correct answer.

Genes and Inheritance

1. Which one of the following is the number of chromosomes from mother, present in each cell of a person?

   i. 22

   ii. 23

   iii. 44

   iv. 46

2. Chromosome A and chromosome B are two homologous chromosomes. Which one of the following has a relation of their chromatids?

   i. Non-sister chromatids

   ii. Nonrelated chromatids

   iii. Related chromatids

   iv. Sister chromatids

3. Which one of the following Nitrogenous Bases is not a part of RNA?

   i. Adenine

   ii. Cytosine

iii. Guanine

iv. Thymine

4. Ribonucleic Acid (RNA) is the integral part of a cell. Which one of the process takes place for the synthesis of RNA?

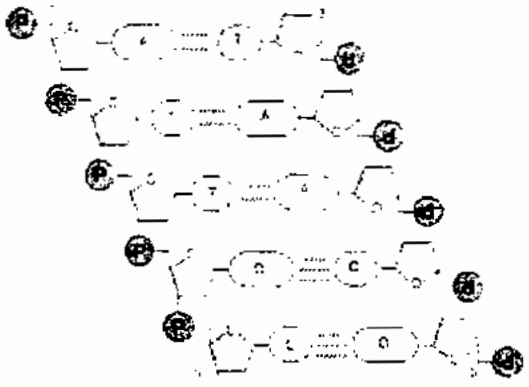
i. Replication

ii. Translation

iii. Transcription

iv. Transformation

5-6. Use the DNA diagram below to answer the following questions.



a. Which one of the following belongs to the composition of nucleotide in the diagram?

i. Adenine-Thymine-Sugar

ii. Adenine-Cytocine-Guanine

iii. Adenine-Cytocine-Thymine

iv. Adenine- Sugar-Phosphate

b. Which one of the following number is correct for the number of nucleosides present in the diagram?

i. 5

ii. 10

iii. 15

iv. 20

7. B+ is blood group of human. Gene controls the formation of this blood group. Which one of the following has a correct series to make B+ blood group by the gene?

i. Protein-translation-transcription- B+

ii. Transcription-protein-translation- B+

iii. Transcription- translation- protein- B+

iv. Translation-transcription-protein- B+

8. Which one of the following combination is same in DNA of human and Rabbit?

i. A+T : C+G

ii. A+C : T+G

iii. A+G : T+C

iv. A+U : C+G

9. Mr. Ahmed and his wife are heterozygous normal for Diabetes. Which one of the chance of their diabetic baby born.

i. Zero

ii. 1/4

iii. 1/2

iv. 3/4

10. The carbon isotope is attached with the both strands of a DNA molecule. Which one of the following number of strands will have carbon isotope after two replications?

i. 02

ii. 04

iii. 06

iv. 08

11. In a pea plant, Red flowers(R) are dominant to white flowers(r) and tallness (T) is dominant to dwarfness (t). A heterozygous plant (Rr Tt) is crossed with double recessive plant (rr tt). Which one of the following could be the expected percentage of offsprings?

i.	Red tall	Red dwarf	White tall	White dwarf
	25%	25%	25%	25%
ii.	Red tall	Red dwarf	White tall	White dwarf
	25%	25%	49%	1%
iii.	Red tall	Red dwarf	White tall	White dwarf
	49%	1%	49%	1%
iv.	Red tall	Red dwarf	White tall	White dwarf
	1%	1%	49%	49%

12. Parents of Ali are colour blind. Ali is also colour blind. Which one of the following is responsible for the colour blindness of Ali.

i. His father

ii. His mother

iii. Ali himself

iv. His father and mother both

13. A pea plant is self pollinated. Mr.Saif Ali germinated 200 seeds of pea plant of same trait, which one of the following number of seedlings would have parental characteristics?

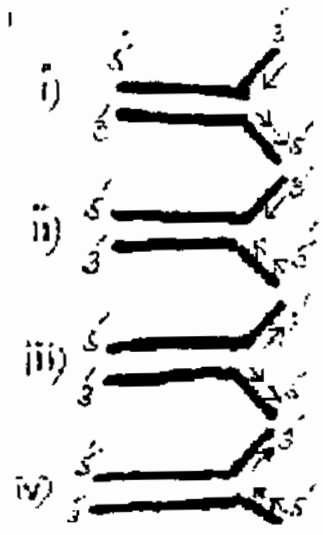
i. 25%

ii. 50%

iii. 75%

iv. 100%

14. Which one of the following diagrams correctly represents the manner of replication of DNA?



15. When the DNA triplet (CTT) in a gene is changed in to CAT. Which one of the following term will be used for this change?

i. Modification

ii. Variation

iii. Evolution

iv. Point mutation

16. Which one of the following statement regarding " okazaki fragment" is correct?

i. Double stranded DNA fragment

ii. Single stranded DNA fragment

iii. Single stranded mRNA fragment

iv. Single stranded tRNA fragment

17. The colour of eyes of a person is blue. Which one of the following terms indicates the colour of blue eyes?

i. Genome

ii. Genotype

iii. Karyotype

iv. Phenotype

18. Haroon is normal (HbA/HbA) but his wife is sickled cell patient(Hbs/Hbs).Which one of the following will be percentage of sicked cell disease in their children?

i. 0%

ii. 25%

iii. 50%

iv. 100%

Evolution

19. Which one of the process is the gradual and continuous process of modification?

i. Biodiversity

ii. Evolution

iii. Growth

iv. Variation

20. According to the Lamarck, the organs which are used more are:

i. Better developed

ii. Completely lost

iii. Less developed

iv. Remained same

21. Which one of the following is the example of discontinuous variation?

i. Blood group of human

ii. Colour of human skin

iii. Height of human

iv. Weight of human

22. Which one of the following are Analogous organs?

i. Legs of donkey and horse

ii. Legs of parrot and pigeon

iii. Wings of parrot and pigeon

iv. Wings of sparrow and butterfly

23. Appendix in human is non functional and is functional in Herbivores, so these organs are Homologous. Which one of the following process shows the above statement?

i. Convergent evolution

ii. Divergent evolution

iii. Modification

iv. Variation

24. What is common to whale, seal and shark?

i. Divergent Evolution

ii. Convergent evolution

iii. Homoeothermy

iv. Seasonal migration

25. Adaptation related to high altitude is

i. The increase in RBC Count

ii. The decrease in RBC Count

iii. Increase in WBC Count

iv. Decrease in WBC Count

26. Which one of the following is the part of Lamarckism?

i. Over production

ii. Natural selection

iii. Competition for survival

iv. Inheritance of acquired characters

27. According to Darwin theory of evolution, all the ancestral Giraffe had

i. long necks

ii. short necks

iii. medium necks

iv. variety of necks

Environmental Biology

28. 200 same types of fish in a pond on August 9, 2019 were present. Which one of the following terms will be used for the number of fish in a pond?

i. Community

ii. Species

iii. Population

iv. Family

29. Sun light, temperature, air and water are examples of

i. Biotic factor

ii. Abiotic factor

iii. Nutrients

iv. Mineral resources

30. A lion kills and eats the deer in a jungle. Which one of the relationship is present between lion and deer?

i. Symbiosis

ii. Competition

iii. Predation

iv. Mutualism

31. Zebras and lions live in grassland. Which one of the Trophic level the lions have?

i. Trophic level 1

ii. Trophic level 2

iii. Trophic level 3

iv. Trophic level 4

32. Which one of the following has highest energy level in a jungle?

i. Rabbit

ii. Wild cat

iii. Grass

iv. Lion

33. When the wheat plant absorbs nitrates through roots and makes the part of its body. Which one of the following process indicates the above statement?

i. Nitrogen fixation

ii. Nitrification

iii. Assimilation

iv. Denitrification

34. A deer uses water, grass, light and air in its environment. Which one of the following relationship, the deer has with these things?

i. Ecosystem

ii. Ecology

iii. Mutualism

iv. Commensalism

35. Nitrogen fixing bacteria are present in the roots of peanut plant. Bacteria provide nitrogen to plant and in return plant gives food and protection to bacteria. which one of the relationship they have?

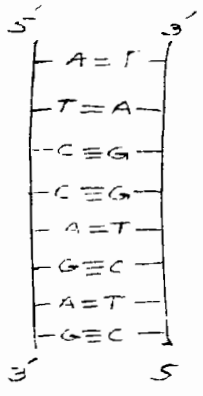
i. Parasitism
ii. Mutualism
iii. Commensalism
iv. Predation

36. Which one of the following organisms in an ecosystem are responsible for the recycling of organisms?

i. Plants
ii. Herbivores
iii. Carnivores
iv. Decomposers

Long Essay Question (LEQ)

1. Use the DNA diagram below to answer the following question.



Draw the replicated forms of the DNA. Explain the process of replication of DNA and Justify, this is semi conservative replication. (10)

Critical Thinking Test

How Clearly Can You Think?

Here is an opportunity to use your brains!

Try every question carefully.

The outcomes from this will not affect your school marks in any way.

Your Name: .....Your Class: .....

(1) Abdullah was talking to Khalid about global warming. Abdullah said that it was happening very fast as the ice-cap at the North pole was melting rapidly. Khalid was not so sure. He remembered that some countries in the Middle East had faced frost and snow for the first time in living memory.

How can we be sure if global warming really is happening?

(A) Believe Abdullah as he talks sense

(B) Read scientific books

(C) Talk to experts like university professors

(D) Collect as much information as possible about global warming

(E) Assume global warming is true and act accordingly

(F) Look at information which has already been gathered through research

(G) Accept what the majority of people believe is true about global warming

Arrange these suggested answers in order of their importance by placing the letters A, B, C...etc. in the boxes below.

The letter which comes first is the ***most*** important and the letter which comes last is the ***least*** important for you.

most important ☐ ☐ ☐ ☐ ☐ ☐ ☐ *least important*

(2) This report appeared in a well known paper:

"Two workmen were suffocated in a tragic industrial accident when they were overcome by

fumes in a large tank where electrical-welding was taking place. Afterwards, a detective said

that, "burning argon gas in the welders torch apparently used up all the oxygen in the tank".

Here are five parts of the newspaper report.

Put one tick on each line to show whether you think the statement is true or false.

	TRUE	FALSE
Workmen were suffocated	XX	
They were overcome by fumes	XX	
They were doing electrical welding	XX	
Argon was burning		XX
The oxygen was used up		XX
Electrical welding does not use of oxygen	XX	

(3) Work out the next number in each sequence of numbers:

(a) 0 2 6 12 20 **30**

(b) 1 2 3 5 7 11 13 **17**

(c) 2 8 18 32 **50**

(4) The biology teacher is warning her students about the dangers of smoking cigarettes. He states that smoking will cause lung cancer.

Ali did not believe that. He told the teacher: '*My grandfather is 76 and has smoked for at least 60 years.*'

*Tick **all** the boxes where the statement supports the view of the biology teacher.*

☐ (A) Ali's grandfather is old

☐ (B) Cigarettes do not kill all smokers

☐ (C) There is no connection between smoking and lung cancer

☐ (D) Smoking increase the chances of early death

☐ (E) Ali's grandfather was fortunate

☐ (F) Lung cancer is not always caused by smoking

☐ (G) Old men do not all die of lung cancer

☐ (H) There were no health warnings on cigarette packets when the grandfather was young

(5) Some liquid nitrogen (at a temperature of -196°C) was poured over a balloon. The balloon shrank in size very rapidly and then returned to its original size after several minutes. The table offers some explanations of what was happening.

*Tick **one** box on each line to show whether you think each reason is reasonable or not*

Reason for Balloon to shrink	**TRUE**	**FALSE**
The air molecules inside the balloon get smaller as it gets colder		XX
The air molecules inside the balloon get closer together as it gets cooler	XX	
The air molecules escape from inside the balloon		XX
Everything gets smaller as it gets Cooler	XX	
The rubber of the balloon becomes less flexible as it gets cooler		XX

(6) Statistics taken from official records for 2006 in Saudi Arabia showing the rates of infant

mortality from birth to the age of ten were published in a newspaper.

Age	**Boys**	**Girls**	**Total**
Under 1 year	**17**	**25**	**42**
1 year	**6**	**2**	**8**
2 years	**4**	**0**	**4**
3 years	**10**	**3**	**13**
4 years	**6**	**4**	**10**
5- 10 years	**5**	**6**	**11**
Total	**48**	**40**	**88**

The newspaper report made six comments.

Tick one box on each line to show whether you think the statement is true or false

Newspaper Comments	TRUE	FALSE
Most of the deaths occur under age 1	Xx	
Under age 10, boys tend to die more than girls	Xx	
Children's nurses are not doing their jobs properly		Xx
Most deaths were caused by neglect		Xx
No children over the age of 10 die		Xx
There is no difference in the numbers of boys and girls dying between birth and age 2	Xx	

(7) You may never have seen sodium fluoride.

It is a white solid which looks very like salt.

Experiments have shown that:

(a) Sodium fluoride contains the elements sodium and fluorine only.

(b) A solution of sodium fluoride in pure water conducts electricity well.

(c) When electricity is passed through the sodium fluoride solution in water, hydrogen and

oxygen are always obtained.

Look at these statements, which of the following is true? *(Tick **one** box next to the true statement)*

☐ Sodium fluoride contains hydrogen and oxygen

☐ Water contains hydrogen and oxygen only

☐ Hydrogen and oxygen are everywhere

☐ Water contains hydrogen and oxygen

Appendix 5

Ability wise students through AES, Government High School (Boys) Satellite town, Quetta

(Experimental Group & Control Group)

S.NO	Experimental group	AES%(9^{TH})	Control group	AES%(9^{TH})
1	Hammad	71	Faisal	71
2	Mehmood	68	Fazal	68
3	Noorahmed	68	Noorullah	68
4	Sultan ahmed	67	Hikmatullah	67
5	Mujeeb	66	Zain	66
6	Nazeer	64	Barkat	64
7	Attaullah	63	Muneer	63
8	Amanullah	63	Amin	62
9	Atteeq	62	Tariq	62
10	Bilal	62	Jameel	62
11	Shakoor	62	Razzaq	62
12	Haider	62	Sheraz	62
13	Aqeel	61	Basit	61
14	Saif	60	Wali	60
15	Majeed	60	Naseebullah	60
16	Ali	60	Khan Muhammad	60
17	Saleem	59	Muhammad jan	59
18	Kareem	58	Inamullah	58
19	Hakeem	57	Sultan	57
20	Niaz	57	Mubeen	57
21	Haris	57	Amjad	57
22	Usman	56	Asjad	56
23	Hameed	56	Habib	56
24	Lateef	56	Ehsan	56
25	Muneeb	56	Raziq	56
26	Qadir	54	Nazeer	54
27	Quddus	53	Akbar	53
28	Farooq	53	Ibraheem	53
29	Hikmat	53	Shafqat	53
30	Niaz	52	Anjum	53
31	Rasheed	52	Jahangir	52
32	Waleed	52	Ajab	52
33	Barkat	50	Maalik	50
34	Azam	50	Shahid	50
35	Sohail	50	Anwar	50
36	Denial	50	Hakeem	50

Appendix 6

Ability wise students through AES, Government High School (Girls) Satellite town, Quetta

(Experimental Group& Control Group)

S.NO	Experimental Group	AES%(9^{th})	Control Group	AES%(9^{th})
1	Aqsa	72	Laraib	72
2	Nadia	70	Memena	70
3	Amna	69	Sitara	69
4	Nor	69	Saima	69
5	Ayesha	69	Asma	69
6	Zainab	69	Shazia	69
7	Harem	69	Ambreen	69
8	Gul	68	Palwasha	69
9	Bano	68	Gulrukh	68
10	Sitara	68	Akhtar	68
11	Aziza	68	Anam	68
12	Naila	68	Momna	68
13	Shazia	68	Sabira	68
14	Lalarukh	68	Faiza	68
15	Farhat	67	Asghari	68
16	Asma	67	Tayyaba	67
17	Saima	67	Saeeda	67
18	Kalsoom	66	Rubina	66
19	Naseem	66	Maryam	66
20	Momna	66	Shehla	65
21	Komal	65	Tooba	65
22	Malaika	65	Khadija	65
23	Nasreen	65	Salma	65
24	Eman	65	Ayesha	65
25	Shamim	64	Aasfa	64
26	Shaista	64	Rasheeda	64
27	Aalia	64	Mehtab	63
28	Batool	63	Anjuman	63
29	Zainab	63	Shagufta	63
30	Anjum	62	Iqra	62
31	Imtiaz	62	Qaria	62
32	Amna	62	Saba	62
33	Ayesha	62	Memona	62
34	Anam	61	Hafsa	61
35	Mumtaz	61	Haseena	61
36	Rukhsana	61	Jannat	61

Appendix 7

Table of Specification

objectives	**Units**	**% age of content**	**No. of items**
Clarity	Genes and inheritance Evolution Environmental biology	50 25 25	2 1 1
accuracy	Genes and inheritance Evolution Environmental biology	50 25 25	2 1 1
precision	Genes and inheritance Evolution Environmental biology	50 25 25	2 1 1
relevance	Genes and inheritance Evolution Environmental biology	50 25 25	2 1 1
Depth	Genes and inheritance Evolution Environmental biology	50 25 25	2 1 1
Breadth	Genes and inheritance Evolution Environmental biology	50 25 25	2 1 1
Logic	Genes and inheritance Evolution Environmental biology	50 25 25	2 1 1
significance	Genes and inheritance Evolution Environmental biology	50 25 25	2 1 1
Fairness	Genes and inheritance Evolution Environmental biology	50 25 25	2 1 1
Total			36 items

Content Validity
Multiple Choice Questions (MCQs)

Note: Each question is followed by four options. Encircle the correct answer.

Genes and Inheritance

1. Which one of the following is the number of chromosomes from mother, present in each cell of a person?

i. 22
ii. 23
iii. 44
iv. 46

Standard of Paul-Elder Critical Thinking Model	Assessment of Clarity (Item No.1)
Clarity	According to Paul & Elder (2013) "clarity is to be clear about concept having concrete example in a particular content". The information in this question is clear, not vague and confused so the question shows clarity and is the concrete example of the number of chromosomes in human cell. How much student understands the concept of number of chromosomes in one cell of human?

2. Chromosome A and chromosome B are two homologous chromosomes. Which one of the following has a relation of their chromatids?

i.Non-sister chromatids
ii.Nonrelated chromatids
iii.Related chromatids
iv.Sister chromatids

Standard of Paul-Elder Critical Thinking Model	Assessment of Clarity (Item No.2)
Clarity	According to Paul & Elder (2013) "clarity is to be clear about concept having concrete example in a particular content" The information in this question is clear, not vague and confused so the question shows clarity having concrete example of shape of chromosomes. How much student understands the concept of shape of chromosomes in one cell of human?

3. Which one of the following Nitrogenous Bases is not a part of RNA?

i. Adenine

ii. Cytosine

iii. Guanine

iv. Thymine

Standard of Paul-Elder Critical Thinking Model	Assessment of Accuracy (Item No. 3)
Accuracy	According to Paul & Elder (2013) "Accuracy is the correctness of the content or information" The information given in the question is really true so the question shows Accuracy. How much student understands the concept of structure of RNA.

4. Ribonucleic Acid (RNA) is the integral part of a cell. Which one of the process takes place for the synthesis of RNA?

   i. Replication

   ii. Translation

   iii. Transcription

   iv. Transformation

Standard of Paul-Elder Critical Thinking Model	;ment of Accuracy (Item No.4)
Accuracy	According to Paul & Elder (2013) "Accuracy is the correctness of the content or information" The information given in the question is really true so the question shows Accuracy. How much student understands the concept of Transcription.

5-6 Use the DNA diagram below to answer the following questions.

a. Which one of the following belongs to the composition of nucleotide in the diagram?

   i. Adenine-Thymine-Sugar

   ii. Adenine-Cytocine-Guanine

   iii. Adenine-Cytocine-Thymine

   iv. Adenine- Sugar -Phosphate

Standard of Paul-Elder Critical Thinking Model	**Assessment of Precision (Item No.5)**
Precision	According to Paul & Elder (2013) "Precision is the specification of the concept". In this question students must remain specific in their thinking about the structure of Nucleotide in DNA.

b. Which one of the following number is correct for the number of nucleosides present in the diagram?

   i. 5

   ii. 10

   iii. 15

   iv. 20

Standard of Paul-Elder Critical Thinking Model	**Assessment of Precision (Item No.6)**

Precision	According to Paul & Elder (2013) "Precision is the specification of the concept". In this question students must remain specific in their thinking about the structure of Nucleoside in DNA.

7. B+ is blood group of human. Gene controls the formation of this blood group. Which one of the following has a correct series to make B+ blood group by the gene?

i. Protein-translation-transcription- B+

ii. Transcription-protein-translation- B+

iii. Transcription- translation- protein- B+

iv. Translation-transcription-protein- B+

Standard of Paul-Elder Critical Thinking Model	**Assessment of Relevance (Item No.7)**
Relevance	According to Paul & Elder (2013) "Relevance is the information relate to solve the problem" The information in the question is relevant to the topic "Genes and Inheritance". Student will relate the information with the concept of "function of gene" to solve the problem.

8. Which one of the following combination is same in DNA of human and Rabbit?

i. A+T : C+G

ii. A+C : T+G

iii. A+G : T+C

iv. A+U : C+G

Standard of Paul-Elder Critical Thinking Model	**Assessment of Relevance (Item No.8)**
Relevance	According to Paul & Elder (2013) "Relevance is the information relate to solve the problem" The information in the question is relevant to the topic "Genes and Inheritance". Student will relate the information with the concept of "structure of DNA" to solve the problem.

9. Mr. Ahmed and his wife are both heterozygous normal for Diabetes. Which one of the chance of their diabetic baby born.

i. Zero

ii. ¼

iii. ½

iv. 3/4

Standard of Paul-Elder Critical Thinking Model	**Assessment of Depth (Item No.9)**
Depth:	According to Paul & Elder (2013) "Depth is the thinking complexity of the concept". Analysis level concept is required to analyse the Dominancy of alleles in heterozygous condition of genetics.

10 The carbon isotope is attached with the both strands of a DNA molecule. Which one of the following number of strands will have carbon isotope after two replications?

i. 02

ii. 04

iii. 06

iv. 08

Standard of Paul-Elder Critical Thinking Model	**Assessment of Depth (Item No.10)**
Depth	According to Paul & Elder (2013) "Depth is the thinking complexity of the concept". Depth is the thinking complexity of the concept. Analysis level concept is required to analyze the replication of DNA.

11. In a pea plant, Red flowers(R) are dominant to white flowers(r) and tallness (T) is dominant to dwarfness (t). A heterozygous plant (Rr Tt) is crossed with

double recessive plant (rr tt). Which one of the following could be the expected percentage of offsprings?

i. Red tall Red dwarf White tall White dwarf

25% 25% 25% 25%

ii. Red tall Red dwarf White tall White dwarf

25% 25% 49% 1%

iii. Red tall Red dwarf White tall White dwarf

49% 1% 49% 1%

iv. Red tall Red dwarf White tall White dwarf

1% 1% 49% 49%

Standard of Paul-Elder Critical Thinking Model	**Assessment of Breadth (Item No.11)**
Breadth	According to Paul & Elder (2013) "Broadness is to look at the information from another perspective". A vast concept of "Dominance in Genetics" at the certain level is required to solve this problem in the perspective of plants; this concept can also be used in animals and human.

12. Parents of Ali are colour blind. Ali is also colour blind. Which one of the following is responsible for the colour blindness of Ali.

i. His father

ii. His mother

iii. Ali himself

iv. His father and mother both

Standard of Paul-Elder Critical Thinking Model	**Assessment of Breadth (Item No.12)**
Breadth	According to Paul & Elder (2013) "Broadness is to look at the information from another perspective" A vast concept of Sex linked inheritance is required to answer the question in human. Information of sex linked inheritance can be used in animals and in plants.

13. A pea plant is self pollinated. Mr.Saif Ali germinated 200 seeds of pea plant of same trait. Which one of the number of seedlings would have parental characteristics?

i. 25%

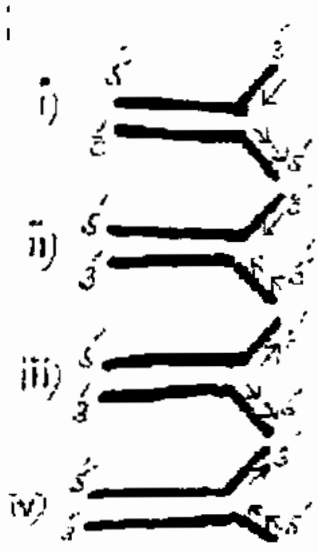
ii. 50%

iii. 75%

iv. 100%

Standard of Paul-Elder Critical Thinking Model	Assessment of logic (Item No.13)
Logic	According to Paul & Elder (2013) "Logic is to provide evidence and reasoning of information" This question requires evidence and reasoning about pollination of self pollinated plant.

14. Which one of the following diagrams correctly represents the manner of replication of DNA?



Standard of Paul-Elder Critical Thinking Model	Assessment of logic (Item No.14)

Logic:	According to Paul & Elder (2013) "Logic is to provide evidence and reasoning of information" This question requires evidence and reasoning about the manner of replication of DNA.

15. When the DNA triplet (CTT) in a gene is changed in to CAT. Which one of the following term will be used for this change?

i. Modification

ii. Variation

iii. Evolution

iv. Point mutation

Standard of Paul-Elder Critical Thinking Model	**Assessment of Significance (Item No.15)**
Significance	According to Paul & Elder (2013) "Significance is to focus on most important facts and central idea" The information about the concept of replication of DNA is significant and important for the students in further learning.

16. Which one of the following statement regarding " Okazaki fragment" is correct?

i. Double stranded DNA fragment

ii. Single stranded DNA fragment

iii. Single stranded mRNA fragment

iv. Single stranded tRNA fragment

Standard of Paul-Elder Critical Thinking Model	**Assessment of Significance (Item No.16)**
Significance	According to Paul & Elder (2013) "Significance is to focus on most important facts and central idea" The question about the concept of replication of DNA is significant for the students in further learning about the structure of Okazaki fragments.

17. The colour of eyes of a person is blue. Which one of the following terms indicates the colour of blue eyes?

i. Genome

ii. Genotype

iii. Karyotype

iv. Phenotype

Standard of Paul-Elder Critical Thinking Model	Assessment of Fairness (Item No.17)
Fairness	According to Paul & Elder (2013) "Fairness is justifiable thinking in the context" The information in this question display fairness having a justification of the term phenotype.

18. Haroon is normal (HbA/HbA) but his wife is sickled cell patient (Hbs/Hbs).

Which one of the following will be percentage of sicked cell disease in their children?

i. 0%

ii. 25%

iii. 50%

iv. 100%

Standard of Paul-Elder Critical Thinking Model	Assessment of Fairness (Item No.18)
Fairness	According to Paul & Elder (2013) "Fairness is justifiable thinking in the context" The information in this question displays fairness and justification of Autosomal recessive characteristics.

Evolution

19. Which one of the process is the gradual and continuous process of modification?

i. Biodiversity

ii. Evolution

iii. Growth

iv. Variation

Standard of Paul-Elder Critical Thinking Model	Assessment of Clarity (Item No.19)
Clarity	According to Paul & Elder (2013) "clarity is to be clear about concept having concrete example in a particular content". The information in this question is not vague and confused so the question shows clarity. How much student understands the concept of evolution?

20. According to the Lamarck, the organs which are used more are

    i. Better developed

    ii. Completely lost

    iii. Less developed

    iv. Remained same

Standard of Paul-Elder Critical Thinking Model	Assessment of Accuracy (Item No. 20)
Accuracy	According to Paul & Elder (2013) "Accuracy is the correctness of the content or information". The information given in the question is really true so the question shows Accuracy. How much student understands the concept of use and disuse of organs.

21. Which one of the following is the example of discontinuous variation?

    i. Blood group of human

    ii. Colour of human skin

    iii. Height of human

    iv. Weight of human

Standard of Paul-Elder Critical Thinking Model	Assessment of Precision (Item No.21)
Precision	According to Paul & Elder (2013) "Precision is the specification of the concept". Students must remain specific in their thinking about the discontinuous variation.

22. Which one of the following are Analogous organs?

i. Legs of donkey and horse

ii. Legs of parrot and pigeon

iii. Wings of parrot and pigeon

iv. Wings of sparrow and butterfly

Standard of Paul-Elder Critical Thinking Model	**Assessment of item No.22 according to Model Standards**
Relevance	According to Paul & Elder (2013) "Relevance is the information relate to solve the problem". The information in the question is relevant to the topic "Evolution". Student will relate the information with the concept of "Analogous organs"

23. Appendix in human is non functional and is functional in Herbivores, so these organs are Homologous. Which one of the following process shows the above statement?

i. Convergent evolution

ii. Divergent evolution

iii. Modification

iv. Variation

Standard of Paul-Elder Critical Thinking Model	**Assessment of item No.23 according to Model Standards**
Depth	According to Paul & Elder (2013) "Depth is the thinking complexity of the concept". Depth is the thinking complexity of the concept. Analysis level concept is required to analyze the divergent evolution.

24. What is common to whale, seal and shark?

i. Adaptive radiation

ii. Convergent evolution

iii. Homoeothermy

iv. Seasonal migration

Standard of Paul-Elder Critical Thinking Model	Assessment of item No.29 according to Model Standards
Accuracy	According to Paul & Elder (2013) "Accuracy is the correctness of the content or information". The information given in the question is really true so the question shows Accuracy. How much student is accurate about the concept of Abiotic factors?

30. A lion kills and eats a deer in a jungle. Which one of the food relationship is present between lion and deer?

i. Symbiosis

ii. Competition

iii. Predation

iv. Mutualism

Standard of Paul-Elder Critical Thinking Model	Assessment of item No.30 according to Model Standards
Precision	According to Paul & Elder (2013) "Precision is the specification of the concept". Students must remain specific in their thinking about the concept of predation.

31. Zebras and lions live in grassland. Which one of the Trophic level the lions have?

i. Trophic level 1

ii. Trophic level 2

iii. Trophic level 3

iv. Trophic level 4

Standard of Paul-Elder Critical Thinking Model	Assessment of item No.31 according to Model Standards
Relevance	According to Paul & Elder (2013) "Relevance is the information relate to solve the problem". The information in the question is relevant to the topic "Environmental Biology". Student will relate the information with the concept of "Trophic Level"

32. Which one of the following has highest energy level in a jungle?

i. Rabbit

ii. Wild cat

iii. Grass

iv. Lion

Standard of Paul-Elder Critical Thinking Model	Assessment of item No.32 according to Model Standards
Depth	According to Paul & Elder (2013) "Depth is the thinking complexity of the concept". Analysis level concept is required to differentiate Energy levels of food chain.

33. When the wheat plant absorbs nitrates through roots and makes the part of its body. Which one of the following process indicates the above statement?

i. Nitrogen fixation

ii. Nitrification

iii. Assimilation

iv. Denitrification

Standard of Paul-Elder Critical Thinking Model	Assessment of item No.33 according to Model Standards
Breadth:	According to Paul & Elder (2013) "Broadness is to look at the information from another perspective". Broadness of the knowledge is the breadth. Nitrogen cycle is a vast concept can also be used in geological and environmental sciences.

34. A deer uses water, grass, light and air in its environment. Which one of the following relationship, the deer has with these things?

i. Ecosystem

ii. Ecology

iii. Mutualism

iv. Commensalism

Standard of Paul-Elder Critical Thinking Model	Assessment of item No.34 according to Model Standards
Logic	According to Paul & Elder (2013) "Logic is to provide evidence and reasoning of information" This question requires thinking and reasoning about the concept of Ecology.

35. Nitrogen fixing bacteria are present in the roots of peanut plant. Bacteria provide nitrogen to plant and in return plant gives food and protection to bacteria. which one of the relationship they have?

i. Parasitism

ii. Mutualism

iii. Commensalism

iv. Predation

Standard of Paul-Elder Critical Thinking Model	Assessment of item No.35 according to Model Standards
Significance	According to Paul & Elder (2013) "Significance is to focus on most important facts and central idea". The information about the concept of Mutualism is significant for the students and important to understand the concept for further learning.

36. Which one of the following organisms in an ecosystem are responsible for the recycling of organisms?

i. Plants

ii. Herbivores

iii. Carnivores

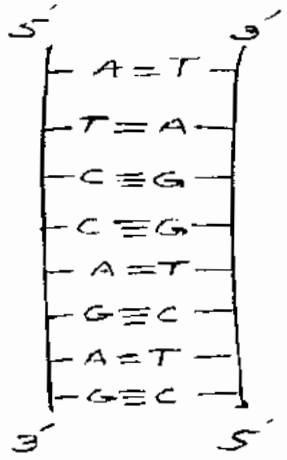
iv. Decomposers

Standard of Paul-Elder Critical Thinking Model	Assessment of item No.36 according to Model Standards
Fairness	According to Paul & Elder (2013) "Fairness is justifiable thinking in the context" Do the students display fairness about the concept of Decomposers?

Rubric

Long Essay Question (LEQ)

Use the DNA diagram below to answer the following question.



Draw the replicated forms of the DNA. Explain the process of replication of DNA and Justify, this is semi conservative replication. (10)

Holistic Rubric for scoring the standards of Paul-Elder Critical Thinking Model

Scores	Description
10	The concept of "Replication of DNA" is clear and not vague and confused so the concept shows clarity. The information given is really true shows Accuracy. Information is precise and relate with the topic. Complexity and vast concept is required. The information have reasoning and significant for the students in learning. The answer is to the point and having command on the concept.
9	The concept of "Replication of DNA" is clear and not vague and confused so the concept shows clarity. The information given is really true shows Accuracy. Information is precise and relate with the topic. Complexity and vast concept is present. The information have reasoning and significant for the students in learning. The answer is mostly to the point but having command on the concept
8	The concept of "Replication of DNA" is clear and not vague and confused so the concept shows clarity. The information given is really true shows Accuracy. Information is precise and relate with the topic. Complexity and vast concept is present. The information have less reasoning and significant for the students in learning. The answer is not to the point but having command on the concept
7	The concept of "Replication of DNA" is clear and not vague and confused so the concept shows clarity. The information given is

	really true shows Accuracy. Information is precise and relate with the topic. Complexity and vast concept is present. The information have less reasoning and less significant for the students in learning. The answer is not to the point but having command on the concept
6	The concept of "Replication of DNA" is clear and not vague and confused so the concept shows clarity. The information given is really true shows Accuracy. Information is precise and relate with the topic. Information shows complexity but broadness of concept is missing. The information have less reasoning and less significant for the students in learning. The answer is not to the point and having not command on the concept
5	The concept of "Replication of DNA" is clear and not vague and confused so the concept shows clarity. The information given is really true shows Accuracy. Information is precise and relate with the topic. Both complexity and broadness of concept is missing. The information have less reasoning and less significant for the students in learning. The answer is not to the point and having not command on the concept
4	The concept of "Replication of DNA" is clear and not vague and confused so the concept shows clarity. The information given is really true shows Accuracy. Information is not proper precise and relate with the topic. Both complexity and broadness of concept is missing. The information have less reasoning and less significant for the students in learning. The answer is not to the point and having not command on the concept
3	The concept of "Replication of DNA" is clear and not vague and confused so the concept shows clarity. The information given is really true shows Accuracy. Information is not proper precise and dilate from the topic. Both complexity and broadness of concept is missing. The information have less reasoning and less significant for the students in learning. The answer is not to the point and having no command on the concept
2	The concept of "Replication of DNA" is clear and not vague and confused so the concept shows clarity. The information has mistakes having less Accuracy. Information is not proper precise and dilate from the topic. Both complexity and broadness of concept is missing. The information have less reasoning and less significant for the students in learning. The answer is not to the point and having no command on the concept
1	The concept of "Replication of DNA" is unclear, vague and confused so the concept do not show clarity. The information has mistakes having less Accuracy. Information is not proper precise and dilate from the topic. Both complexity and broadness of concept is missing. The information have less reasoning and less significant for the students in learning. The answer is not to the point and having no command on the concept.

Appendix 10

No.C-12/CP/3756-61/G.B.
DIRECTORATE OF EDUCATION (S)
BALOCHISTAN ,QUETTA.

Dated Quetta the 17th September, 2019.

To:

The Principal/Headmaster/Headmistress.
Government Boys/Girls High School.
Sattelite Town Quetta.

Subject:- **PERMISSION TO TEACH BIOLOGY CLASS 10TH TO CONDUCT Ph.D RESEARCH.**

Enclosed find herewith a copy of self explanatory application submitted by Mr. Abdul Majeed, Assistant Professor, Government College of Education Quetta.

Permission is hereby accorded to Mr. Abdul Majeed Assistant Professor to teach Biology Class 10th in your school for conduct of Ph.D Research work on " Effect of Paul-Elder Critical Thingking Model on the Academic Achievement of Science Students at Secondary Level in Balochistan. The duration of his stay will be approximately 08-weeks (two months).

You are directed to accommodate the Researcher for Biology periods and provide facilities and exend full cooperation. This will also beneficial and useful for students.

17/9/2019

Director of Education (Schools)
Balochistan Quetta.

Copy to:--

1. The District Education Officer, Quetta.
2. The District Officer Education(Female) Quetta.
3. Mr. Abdul Majeed, Assistant Professor.

Appendix 11

Normality distribution of achievement scores (male group)

Construct	Groups	Skewness	Standard Error	2 SE	Comment
Overall Male	Experimental	-0.531	0.393	0.786	Normal
	control	0.497	0.393	0.786	Normal
Clarity	Experimental	-0.209	0.393	0.786	Normal
	control	-0.515	0.393	0.786	Normal
Accuracy	Experimental	-0.602	0.393	0.786	Normal
	control	-0.290	0.393	0.786	Normal
Precision	Experimental	0.037	0.393	0.786	Normal
	control	0.344	0.393	0.786	Normal
Relevance	Experimental	-0.611	0.393	0.786	Normal
	control	0.259	0.393	0.786	Normal
Depth	Experimental	-0.614	0.393	0.786	Normal
	control	0.775	0.393	0.786	Normal
Breadth	Experimental	-0.360	0.388	0.776	Normal
	control	0.343	0.398	0.796	Normal
Logic	Experimental	-0.020	0.393	0.786	Normal
	control	0.630	0.393	0.786	Normal
Significance	Experimental	-0.575	0.393	0.786	Normal
	control	0.373	0.393	0.786	Normal
Fairness	Experimental	-0.037	0.393	0.786	Normal
	control	0.323	0.393	0.786	Normal

Normality distribution of achievement scores (Female groups)

Construct	Groups	Skewness	Standard Error	2 SE	Comment
Overall Male	Experimental	-0.676	0.393	0.786	Normal
	control	0.124	0.393	0.786	Normal
Clarity	Experimental	-0.192	0.393	0.786	Normal
	control	0.233	0.393	0.786	Normal
Accuracy	Experimental	-0.753	0.393	0.786	Normal
	control	0. 454	0.393	0.786	Normal
Precision	Experimental	-0.233	0.393	0.786	Normal
	control	-0.287	0.393	0.786	Normal
Relevance	Experimental	-0.765	0.393	0.786	Normal
	control	0.044	0.393	0.786	Normal
Depth	Experimental	-0.511	0.393	0.786	Normal
	control	-0.209	0.393	0.786	Normal
Breadth	Experimental	-0.682	0.388	0.776	Normal
	control	-0.522	0.398	0.796	Normal
Logic	Experimental	-0.007	0.393	0.786	Normal
	control	0.693	0.393	0.786	Normal
Significance	Experimental	0.487	0.393	0.786	Normal
	control	-0.682	0.393	0.786	Normal
Fairness	Experimental	0.000	0.393	0.786	Normal
	control	0.054	0.393	0.786	Normal