

## Scientific Reasoning Ability and Academic Achievement of Secondary School Students

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Abstract

*Scientific reasoning ability is considered as developing ability and is improved through knowledge acquisition. So, the study was opted to find out the relationship between the scientific reasoning ability and the achievement marks of SSC science graduates. All SSC science graduates enrolled in intermediate 1st year class in any public or private college of Punjab were the population. 1620 students from four districts were conveniently selected. The suitable test “Lawson reasoning ability test” was adapted with permission to make it bilingual and pilot testing brought Cronbach’s  $\alpha$  value 0.914. Test was administered to 1620 students of both public and private colleges whereas returned rate was 93.7%. Results calculated through descriptive statistics and Pearson Correlation was “no significant relationship between reasoning ability test scores and the SSC marks”. It was recommended that assessment agencies i.e. Board of intermediate and Secondary education may include the items of higher order thinking in assessment.*

**Key Words:** Scientific Reasoning, Ability testing, Academic Achievement & Secondary School Science Students

### Introduction

Expansion of the learning objectives is necessary that relate to course and discipline-specific concepts. Accentuating the expansion of learners’ reasoning skills and the accomplishment of procedural information is a suitable way for the existing advancement of students’ reasoning abilities ([Kulasegaram & Rangachari, 2018](#)). According to [Darling-Hammond, Flook, Cook-Harvey, Barron, & Osher, \(2019\)](#) learning is progress of individual as an outcome of supportive collaboration. It consists of the development that empowers the student to work in a good way in his environment, improve and adapt behaviors that enable him to have healthy relationships and achieve personal success.

In furthest traditional education settings, teaching and learning emphasize on training of content knowledge and it is expected that constant and laborious content learning will help to develop students’ general reasoning abilities. However, there are many accepted research evidences that prove that this relationship exists ([Mahmood, 2017](#)). Mostly work in education research also emphasizes students learning of content knowledge while research on student general scientific abilities has been attaining fame in recent years. According to [Zimmerman \(2005\)](#) scientific reasoning of children is understudy from previous a number of years and scientific reasoning involves various collection of cognitive activities such as conceptual understanding as well as inquiry skills. Scientific reasoning is type of higher order thinking skill. It is relevant to the abilities like identification, analysis, creativity, logical thinking and solving problems ([Novia, & Riandi, 2017](#)). Scientific reasoning develops through the collaboration among persons’ internal factors e.g., metacognitive and cognitive development and contextual and cultural factors ([Tajudin & Chinnappan, 2015](#)). On the other hand, [Lawson \(2003\)](#) defined scientific reasoning as intellectual strategy used in processing information and draw conclusions and these conclusions are more than the direct experiences. Scientific reasoning is necessary to manage daily life problems

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successfully ([Han, 2013](#)). So there is an advancement of new dynamic development in instructional methods and materials that increase students' scientific abilities. Scientific reasoning needs to be developed during academic teacher education in science classrooms and is affected by achievement, cognitive factor in achievement ([Zlatkin, Shavelson, & Kuhn, 2015](#)). In the 21st century students required to develop scientific reasoning for endurance in all disciplines of learning to lead a successful life ([Khoirina, Cari, & Sukarmin, 2018](#)). But according to [Ding, Chabay, Sherwood and Beich, \(2001\)](#) the scientific reasoning ability is not affected by culture and society.

Many assessment studies have proposed a positive correlation between measures of students' abilities in scientific reasoning and their achievement of content learning (Mahmood, 2017; [Kambeyo, 2018](#)). Assessment of scientific reasoning is too different from the assessment of learning of content knowledge. It is relevant to content and reasoning about solutions to content related problems. It is not possible to have an item for assessment of reasoning which has no demand for knowledge ([Adey, & Csapó, 2012](#)). On the theoretical side, a new theory on learning dynamics has been suggested which can deliver a theoretical framework for understanding the interactions between general ability and content learning. The theory also forecasts a series of relations that can be tested by measurement. We have to conduct controlled experiments to understand the interactions between learning of content and the progress of reasoning skills. Scientific reasoning helps the people to deal with the changes in the society. Achievement of scientific literacy is an anticipation of all science education curricula ([Wang, Chen, & Anderson, 2014](#)). Several studies proposed that scientific reasoning is an essential part of scientific knowledge. Similarly, in Thailand, a normal vision of literacy is of an individual: that is indulgent of information and comprehends the connection between science, societal norms and surroundings and incapable to engage himself in intellectual method and reasoning to investigate knowledge. Scientific literacy must improve from the base of pyramid that has three sides ([Zimmerman, 2005](#); Yuenyong & Narjaikaew, 2009; [Lee, & Songer, 2019](#)). It is also indicated by [Lawson \(2009\)](#) that if students have a command on reasoning, they can draw conclusions from a scientific problem ([Fatima, 2008](#)).

Reasoning is about the method of making assumptions from information. There are two types of reasoning. First is termed as deductive if the reality of the preliminary work assures the reality of the results and the second is termed as inductive if the fact of the premises makes the decision feasible ([Moore, & Parker, 2009](#); [Knachel, 2017](#)).

Learning of science requires logical skills and high levels of reasoning ability of students ([Kiswantoa, 2017](#); [Riyanti, Suciati, & Karyanto, 2018](#)). Several formal reasoning approaches are consisting of adjusting variables, probabilistic proportional, co-relational and combinational reasoning abilities that are important for reasoning and to face a scientific problem (Lawson, 2003; Fax, 2009; [Manwaring, Jensen, Gill, Sudweeks, Davies, & Bybee, 2018](#)). Theoretically, it has been said that the reasoning ability enhances with the enhancement of knowledge (Riyanti, Suciati, & Karyanto, 2018). Another viewpoint is that reasoning ability needs specific training, mental ability and practice ([Sherry, Willis, & Caskie \(2013\)](#); [Sternberg, et al., 2000](#)). It is found by [Bird \(2010\)](#) that logical reasoning is counted as the best predictors of the academic performance of students. As it is agreed upon that the education is to empower the students with the reasoning abilities through the attention of teachers, thinkers and academic institutions. In this regard the schools must implement such competencies which focus on the subject and content knowledge as well as scientific reasoning ability (Khoirina, Cari, & Sukarmin, 2018).

According to Educational achievement the level of competence achieved in academic work is often represented by the percentage of marks acquired by students in examinations ([Kohli, 1975](#)). Exploration has exposed that, in addition to upgrading morals in the coming year, school achievement is a symbol of upcoming achievement in life. Better presentation in academics usually tends to endure their level of success in labour too. Educational success also has an important influence on student self-assessment ([Reis, 2007](#)).

In Pakistan the secondary level is terminal stage. It is also preparatory stage for higher secondary level and higher education. At this stage it is said that in public school students are exposed to traditional methods captivating the students for rote memorizing the contents and mostly teach to the test. No scientific reasoning abilities, conceptual understanding or higher order thinking is assessed by the assessment agencies i.e. Board of intermediate and Secondary education those are responsible for certification ([Javed, 2015](#); [Ali, Rizvi, 2007](#)). The institutions claimed that they are divulging quality education as they are earning good grades of the students. It is

necessary to see that the students with good grades have some higher order thinking or not. For the purpose one aspect of higher order thinking i.e. reasoning ability is being assessed.

In Pakistani education system, many students pass the Secondary School Certificate (SSC) examination every year with good grades but when they face a reasoning and application-based test like any entry test they cannot perform well. Here a question arise that reasoning ability and knowledge have any relationship or not. Hence the study is opted to find out the relationship between the scientific reasoning ability and the achievement marks of SSC (science) graduates.

### Objectives of the study

The objectives of the study were to:

- (i) Find out the scientific reasoning ability of SSC (science) graduates.
- (ii) Determine the achievement marks of SSC (science) graduates.
- (iii) Find out the relationship between the scientific reasoning ability and achievement marks of SSC (science) graduates.

Major hypothesis of the study was “There is no significant relationship between the scientific reasoning ability test scores and the achievement marks of SSC (science) graduates”.

### Methodology of the Study

In the present study, descriptive and correlational design was applied to find out the relationship between scientific reasoning ability and the achievement marks of SSC science graduates.

The population consists of SSC science graduates of thirty-eight districts of Punjab (province of Pakistan) passing out in the academic year 2018-19 through 700 pub female’s students of of HSLic and 1400 private colleges in Punjab and enrolled in 1<sup>st</sup> year of any intermediate class at public or private college. To select a sample using multistage random sampling technique at first four districts of Punjab were selected conveniently named Sheikhpura, Multan, Lahore and Sargodha. From each district, 10% colleges both public and private were randomly selected. From each selected college, 10% students (Total 1620; including 850 female & 770 male) were selected on presence basis.

The research instrument in this study was Lawson reasoning ability test (1978) Revised in 2000 which was according to the syllabus and content of local SSC syllabus with permission of the author. Test consists of 24 multiple choice questions (MCQS). The first part of MCQs consists of three options A to C and the second part of the MCQs consists of reasoning-based questions and have five options A to E. This reasoning test was made bilingual (English+Urdu) to make it comprehensible for students. The bilingual instrument was reviewed by the five experts before administration. The pilot testing was conducted on a small sample of 100 students. These students were not included in the actual sample. Cronbach’s  $\alpha$  was applied to calculate the reliability. The reliability of the test was 0.914. The test was administered by the researcher to the students of both public and private colleges of the four districts of Punjab through self-visit. The numbers of tests given to different colleges were 1620 and in return 1519 (including 800 female and 719 male students) forms were received and response rate was 93.7%. Descriptive statistics was applied to determine mean and standard deviation. Pearson Correlation was applied between test score and SSC marks. t-test was applied on test scores and SSC scores with respect to gender, locality and institution.

**Table 1.** Overall Descriptive Statistics on Reasoning Ability Test Scores

Category	Mean / %	SD	t-value	df	p-value
Reasoning ability test scores	10.08 / 42%	4.36	---	---	---
Public	9.85 / 41%	4.45	-1.55	1517	.121
Private	10.2 / 42%	4.30			
Male	9.90 / 41.2%	4.39	-1.55	1517	.121
Female	10.24 / 42.5%	4.32			
Urban	10.2 / 42.5%	4.38	3.92	1517	.000
Rural	9.06 / 37.7%	4.13			

Table 1 shows that the overall mean of test scores was 10.08 & SD= 4.36 which was below average (50%). The t-value = -1.5, df = 1517 and p-value 0.121 > 0.05 shows that there was no significant difference between the mean reasoning ability test scores of students of HSC-I enrolled in public institutions ( $M = 9.85$  &  $SD = 4.45$ ) and mean of students of HSC-I enrolled in private institutes ( $M = 10.2$  &  $SD = 4.30$ ). Hence  $H_0$  is accepted. Hence the mean of reasoning ability score of students of private and public institutes was equivalent.

The t-test value = -1.55 with df = 1517 & p-value 0.121 > .05 shows that there was no significant difference between the mean scores of reasoning ability test of male ( $M=9.9$  &  $SD =4.39$ ) and female students of HSC-I ( $M=10.2$  &  $SD= 4.32$ ). So, the null hypothesis  $H_0$  was accepted. However, the mean of reasoning ability test scores of female and male students of HSC-I was equivalent.

The t-value = 3.92 with df = 1517 & p-value= 0.00<0.05 shows that there was a significant difference between the mean reasoning ability test scores of urban ( $M=10.2$  &  $SD= 4.38$ ) and rural students of HSC-I ( $M=9.06$  &  $SD= 4.13$ ). Hence the  $H_0$  is rejected. The mean of reasoning ability test scores of urban students ( $M = 10.2$ ,  $SD = 4.38$ ) of HSC-I was better than their rural counterparts ( $M = 9.06$ ,  $SD = 4.13$ ).

**Table 2.** Analysis in Overall SSC Marks Of Students

Category	Mean / %	SD	t-value	df	p-value
SSC marks	742 / 67.4%	293.8	---	---	---
Public	721/ 65.5%	369	-2.16	1517	.031
Private	755 / 68.6%	236			
Male	712.74 / 64.7%	130.35	-3.70	1517	.000
Female	768.34 / 69.8%	383.86			
Urban	744 / 67.6%	215	.52	1517	.603
Rural	733 / 66.6%	551			

Table 2 shows that overall mean score of male students SSC marks was 742 (67.4%> 50%) and SD = 239.8 which is better than average. The t value = -2.160 with df = 1517 & p-value .031<.05 shows that there was a significant difference between the mean SSC marks of students of HSC-I enrolled in public and private institutes. Hence the  $H_0$  is rejected. The mean of SSC marks of students of HSC-I enrolled in private institutes ( $M=721$  &  $SD= 369$ ) was better than the students of HSC-I enrolled in public institutes ( $M=713$  &  $SD= 130.3$ ).

The t-value =-3.70 with df = 1517 & p-value= 0.000 < .05 shows that there was a significant difference between the mean of SSC marks of male and female students of HSC-I. Hence the null hypothesis  $H_0$  was rejected. The mean of SSC marks of female students of HSC-I ( $M=768$  &  $SD= 383.3$ ; 69.8%) was better than their counterpart male students of HSC-I ( $M=713$  &  $SD= 130.3$ ; 64.7%).

The t-value = .521 with df=1517 & p-value = .0603>0.05 shows that there was no significant difference between the SSC marks of urban and rural students. So,  $H_0$  is accepted. The mean of SSC marks of urban students of HSC-I ( $M=744$  &  $SD=215$ ; 67.6%) was better than the rural students of HSC-I ( $M=733$  &  $SD= 551$ ; 66.6%).

**Table 3.** Relationship between the reasoning ability test scores and the SSC marks

N	r	Significance
1519	-0.001	.982

Table 3 shows that there was no significant relationship between the reasoning ability test scores and the SSC marks of students of HSC-I of session 2014-2015 as  $r = -0.001$  and the p value was  $.982 > 0.05$ .

### Conclusions

On the basis of the data analysis and findings of the study, the following conclusions were drawn:

- i. Overall students of HSC-I acquired mean score in scientific reasoning ability test score was below average (42%) but on average they have good (67.5% > 50%) academic achievement in the SSC exams.

- ii. Students of HSC- I enrolled in private and public institutions have equivalent reasoning ability but students enrolled in private institutions have better average SSC marks (65.5%) than the students enrolled in public institutions (64.8%).
- iii. Reasoning ability of male and female students of HSC-I was equivalent but average academic achievement of female students in SSC exam (69.8%) was better than male students (64.8%).
- iv. While urban students of the HSC-I have better reasoning ability than their rural counterparts (students of HSC-I); similarly, both urban and rural students of HSC-I has equivalent average academic achievement in SSC exams.
- v. There was no significant relationship between reasoning ability score and academic achievement of SSC exams.

## Discussions

The conclusion that I. Overall students of HSC-I acquired average and below average scientific reasoning ability; they acquired better level of academic achievement in SSC exams (67.5%) which is counted in good and satisfactory categories; the possible reason of these results are that mostly students cannot do better in scientific reasoning ability test due to poor teaching methodologies of teachers and lack of scientific activities and students just cram the concepts.

The result that students of HSC- I enrolled in private and public institutions have equivalent reasoning ability is opposite to the findings of [Anwar, \(2015\)](#) that Private school students had higher reasoning ability as compared to the Government school students. Possible reasons may be that students in Sargodha District mostly have rural background and have equivalent level of abilities.

The conclusion that reasoning ability of male and female students of HSC-I was equivalent is confirming the findings of [Piraksaa, Srisawasdib and Koulc \(2014\)](#) that gender does not significantly impact on students' scientific reasoning ability. Moreover, it may be the possible reason that the teaching methodologies of the teachers follow the assessment patterns adopted by the assessment agencies e.g. Boards of Intermediate and Secondary Education; that is not including assessment of higher order thinking.

The conclusion that urban students of HSC-I have better reasoning ability than their rural counterparts is in line with the findings of [Nambikkai and Veliappan \(2016\)](#) that the higher secondary students of semi urban residents are found to have significantly better reasoning ability in science.

The result that no significant relationship between reasoning ability test scores and SSC marks of students was found is opposite to the study of [Rani \(2017\)](#) who found a strong positive correlation between reasoning ability and academic achievement among secondary school students; possible reason may be that in Pakistan, SSC exams do not measure higher order thinking such as reasoning ability; there only knowledge and comprehension level is measured.

## Recommendations

In Pakistan there is dire need to promote student's reasoning ability because it helps the students to face all the challenges regarding any test or exam and in life also.

It is recommended for the teachers to incorporate scientific skills-oriented activities in their teaching. Further it is also recommended that assessment agencies i.e. Board of intermediate and Secondary education may incorporate the items measuring scientific reasoning in the papers of science subjects. It is also recommended that agencies of coordinating Entry test may incorporate items measuring scientific reasoning in the papers.

Moreover, it is also recommended that administrators of educational institutions may manage the classroom-comb labs so that activities for scientific reasoning skills can be carried out easily.

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