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Science Process Skills among Senior Secondary School Students in relation to their Attitude towards Science

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Abstract

The purpose of the present study was to study the levels of Science process skills among senior secondary school students and its relationship with their attitude towards Science. Further, it also explored the respective influence of demographic variables on skills and the relationship between skills and attitude. The study was both descriptive and correlational in nature. The sample was taken from two senior secondary schools in Aligarh, Uttar Pradesh (India) and consisted of 140 students. Data was collected online using standardized Test of Integrated Science Process Skills and Physical Science Attitude Scale (PSAS)respectively. The collected data were analyzed using descriptive statistics and inferential statistics. The statistical results clearly indicated that the students had of Science process skills of varying levels; gender had no significant influence but academic stream had significant influence on their skills and the relationship between skills and attitude was significant, positive and strong.

Keywords:senior secondary school students, Science, Science process sills, attitude

Introduction

Science is a complex and technical subject, having both theoretical and practical sides. Basically, Science consists of two components: scientific knowledge and the acquisition of scientific knowledge(Özgelen, 2012). Scientific knowledge includes scientific concepts such as facts, principles, laws, hypotheses and theories. The acquisition of scientific knowledge involves cognitive, affective and psychomotor domains. Students

can only gain mastery in Science as an academic subject if their teachers teach them at cognitive, affective and psychomotor levels. Then only, they will be able to integrate knowledge (Cognitive), attitudes (Affective) and skills (Psychomotor)so as to develop a better understanding of scientific concepts and their applications in everyday life.

The acquisition of scientific knowledge mainly depends on Science process skills. Science process skills are transferable intellectual skills, appropriate to all scientific endeavours (NSTA, 2002). Science process skills are the thinking skills that scientists use to construct knowledge in order to solve problems and formulate results(Özgelen, 2012).When scientists conduct experimentations, they use Science process skills to discover scientific knowledge (Abruscato, 1995). Science process skills are necessary to produce and use scientific information, to perform scientific research and solve problems (Aktamis &Ergin, 2008). Science process skills are known as procedural skillsor scientific inquiry abilities (Anderson, 2002;Harlen, 1999). Science process skills are the key dimension of scientific / science literacy(Anderson, 2002;Colvill & Pattie, 2002).

Science process skills are seen as a problem-solving skill in which a problem is presented, a systematic process is carried out in order to arrive to solve the problem (Gagne, Yekovich, & Yekovich, 1993). Science process skills are important to teaching ways of reaching knowledge. The students need the process skills both when doing scientific investigations and during their learning process (Harlen, 2000; Taconis, Ferguson-Hessler & Broekkamp, 2000). Science process skills help students to develop higher order thinking and to have meaningful learning experience (Germann & Aram, 1996; Lee,Hairston, Thames, Lawrence, & Herron, 2002).Acquiring science process skills is considered as “learning how to learn” because children learn how to learn by thinking critically and using information creatively. They continue to learn when making discriminating observations, organising and analysing facts or concepts, giving reasons for particular outcomes, evaluating and interpreting results, drawing justifiable conclusions and predicting what will happen if anything were to be changed (Martin, Sexton, Franklin, & McElroy, 2001).

According to researchers (Brotherton & Preece, 1995; Chiappetta & Koballa, 2002; Özgelen, 2012; Skamp, 1988; Zeidan & Jayosi, 2015), Science process skills can be classified into two categories:Basic and Integrated.

Basic process skills include observing, measuring,classifying, inferring, predictingand communicating.

- **Observing**: It is the most basic skill. It is description of what is actually being seen and perceived. It is all about noting and collecting data about objects and events using appropriate senses or instruments (Abruscato, 1995; Carin, Bass, & Contant, 2005; Zeidan & Jayosi, 2015).
- **Measuring:**It is expressing the amount of an object or substance in quantitative terms. It is a quantitative representation of observation and includes assigning values to variables using instruments and defined units. Skills in measuring require the knowledge to use equipment appropriately and to perform necessary calculations (Abruscato, 1995; Carin, Bass, & Contant, 2005; Zeidan & Jayosi, 2015).
- **Classifying:** It is all about relating objects and events according to their properties or attributes. It is a process used to categorize objects based on similarities, differences and interrelationships among objects (Abruscato, 1995; Carin, Bass, & Contant, 2005; Zeidan & Jayosi, 2015).
- Inferring: It refers to giving an explanation for a particular object or substance in quantitative terms. It includes developing possible conclusions about observations based on prior knowledge (Abruscato, 1995; Carin, Bass, & Contant, 2005; Zeidan & Jayosi, 2015).
- **Predicting:**It refers to forecasting a future occurrence based on past observation or the extension of data. It means making a specific statement about what will happen in the future. Accurate predictions require careful observations and correct measurements (Abruscato, 1995; Carin, Bass, & Contant, 2005; Zeidan & Jayosi, 2015).
- **Communicating:**It refers to sharing relevant ideas through words, diagrams, symbols, or graphics about an object, action or event. It is essential to human endeavour and fundamental to scientific work (Abruscato, 1995; Zeidan & Jayosi, 2015).

Integrated Science process skills include identifying and controlling variables, defining operationally, formulating hypotheses, experimenting,interpreting data and presenting or communicating information. These skills require a more advanced knowledge base.

- **Identifying and controlling variables:** It is an essential skill for successfully managing a scientific investigation (Abruscato, 1995; Carin, Bass, & Contant,

2005). It refers to manipulating and controlling properties that relate to situations or events for the purpose of determining causation (Zeidan & Jayosi, 2015).

- **Defining variables operationally:** It requires boundaries to be considered. Depending on the discipline, an operational definition will vary; for example, in physical science, it is based on what is done and observed. On the other hand, in biological sciences, an operational definition is often descriptive (Abruscato, 1995).
- **Formulating hypotheses:**It is another fundamentals skill based on accurate observations or inferences. It refers to making a statement about a possible relationship in the natural world (Abruscato, 1995). It means stating tentative generalisation of observations or inferences that may be used to explain a relatively larger number of events but that is subject to immediate or eventual testing by one or more experiments(Zeidan & Jayosi, 2015).
- **Experimenting:** It involves all basic and integrated processes, beginning with observations that lead to identifying variables to be controlled, developing operational definitions, constructing and conducting a test, collecting and interpreting data, and, when necessary, modifying hypotheses (Abruscato, 1995). It refers to testing a hypothesis through the manipulation and control of independent variables and noting the effects on a dependent variable; interpreting and presenting results in the form of a report that others can follow to replicate the experiment (Zeidan & Jayosi, 2015).
- **Interpreting data:** It involves other science process skills, such as making predictions, inferences, and hypotheses from collected data. It requires previous experience in observing, classifying and measuring before interpreting data (Abruscato, 1995). It refers to arriving at explanations, inference, or hypotheses from data that have been graphed or placed in a table (Zeidan & Jayosi, 2015).

Both basic and integrated Science process skills are important in any scientific investigation such as conducting projects and carrying out experiments (Zeidan & Jayosi, 2015). Training in appropriate basic skills should be provided to students at primary school level which is a prerequisite to learning the integrated skills at secondary and senior secondary school levels.The integrated skills are the terminal skills for solving problems or doing science experiments (Germann & Aram, 1996). In this study, integrated Science process skills are taken into consideration.

The acquisition of scientific knowledge and Science process skills ensures the development of desirable attitude towards Science among students. Attitudes are general dispositions that stand behind people's evaluations and emotional feelings. Attitudes arise from human needs and are expressions of people's intellectual processes (Wheeler, Goodale, & Deese, 1974). The term attitudes toward science should be used to refer to a general, enduring, positive or negative disposition about science (Thomas, Koballa & Crawley, 1985). An attitude consists of three aspects: affective, cognitive and behavioral (Arnson, Wilson, & Akert, 1994). An affective component consists of an individual's dispositions about the attitude object. A cognitive component is the individual's beliefs or knowledge about the attitude object, and the behavioural component is the individual's predisposition to act toward the attitude object in a particular way (Gall, Gall, & Borg, 2003). The attitude towards Science includes the attitudes toward Science as a subject, Science teachers, Science teaching methods, Science-related activities, interests and careers, scientists and so on (Haladyna & Shaughnessy, 1982). In the present study,a student's attitude towards science is defined as his/her inclination to respond to the subject, or a particular aspect of the subject, in a certain predictable manner. Based on this definition, enjoyment of science, science anxiety, self-confidence, interest in science-related careers and perceived importance of science can all be considered "attitudes" (Siddiqui, 2016).

Background and Rationale of the Study

A number of research studies have been carried out on pre-service teachers and school students. Some studies have demonstrated that pre-service teachers have poor understanding of Science process skills. For instance, Emereole (2009) investigated conceptual understanding of Science process skills among high school pre-service science teachers in Botswana and found that they did not have sufficient conceptual understanding of Science process skills. Mbewe, Chabalengula, and Mumba (2010) found that nearly all pre-service elementary teachers were unable to provide correct definitions and explanations of the basic and integrated Science process skills, but the majority of them provided partially correct and incorrect answers. In a similar study by Chabalengula, Mumba and Mbewe (2012), results showed that pre-service teachers were unable to provide correct definitions of the science process skills, indicating that they had limited conceptual understanding of Science process skills, but they performed well on the test that involved the application of skills in novel situations.Al-rabaani (2014) investigated the

acquisition of science process skills by Omani's pre-service social studies teachers and the results showed that they had moderate acquisition of science process skills and there was no difference due their gender.

Mixed findings were obtained by researchers in their studies conducted at school level. Germann and Aram's (1996) evaluation of American students' performance on integrated skills of analysing, recording data, providing evidence and drawing conclusions, revealed that only 61% of their subjects were able to perform and record the data successfully.In their study on high school students, Beaumont-Walters and Soyibo (2001) found that the students' performance on integrated skills was low and unsatisfactory; their performance in decreasing order was: interpreting data, recording data, generalising, formulating hypotheses band identifying variables. The results of study conducted by Dökme and Aydınlı (2009) indicated that the primary school students' performance on basic science process skills was not satisfactory. But Aydınlı, Dökme, Ünlü, Öztürk, Demir and Benli (2011) found the performance of elementary school students on integrated science process skills satisfactory. Özgelen (2012) investigated Turkish upper primary students' scientific process skills under the theoretical framework of cognitive domain and results indicated significant differences between sixth and seventh grade students at private and public schools; private school students had outscored public school students at both grade levels as far as their performance on Science process skills was concerned. In their study at senior secondary school level, Akinbobola and Afolabi (2010) found that the number of basic process skills developed was significantly higher than the integrated process skills in students.

Downing and Filer (1999) explored the relationship between pre-service elementary teachers' competences in science process skills and attitudes toward Science and found a significant relationship between their science process skills and attitudes toward science. Bang and Baker (2013) investigated the effect of high schools' gender organization on Korean tenth-grade students' Science achievement and their attitudes toward Science and concluded that the male and female students from the co-ed school had significantly higher science achievement and positive attitudes toward Science.Kamba, Giwa, Libata and Wakkala (2018) investigated the relationship between science process skills and attitudes toward Physics among senior secondary school students and findings indicated that the students' knowledge of Science process skills was poor, their attitudes toward Physics were good and there was a significant positive relationship between students' knowledge of Science process skills and their attitudes toward Physics.

Scharmann (1989) pointed out that science process skills foster significant increases in subject matter understanding and science content knowledge, arguing that science content and science process skills should be taught together as they complement each other. Similarly, Rillero (1998) found out that both science content and science process skills are mutually valuable and complementary. Science process skills are the most important factor affecting students' achievements and there is a closerelationship between students' achievement and their Science process skills; (Baser & Durmus, 2010).Conceptual understanding and application of these skills are widely acknowledged as one of the central goals of Science education at school level (Barbosa & Alexander, 2004). It is even more important for senior secondary school students to be skilful in both basic and integrated Science process skills as well as to have positive attitude towards Science if they would like to pursue their higher education in the field of Scienceand apply these skills to novel and everyday life situations. However, a review of the literature reveals that only a few studies at international level have been carried out on acquisition of science process skills by senior school students.Moreover, such studies rarely discuss senior secondary school students' conceptual understanding of and performance on the Science process skills. Despite the emphasis on the teaching of these basic and integrated skills in schools and development of positive attitude towards Science among students, there is a dearth of studies published on senior secondary school students' performance on these skills and their relationship with attitude towards Science. This gives the required motivation to investigators of this study to explore these skills among students in India.

Purpose of the Study

In order to fill in the identified research gaps, the present study is aimed at answering the following research questions:

1. What are the levels of Science process skills among senior secondary school students?
2. What are the levels of science process skills among senior secondary school students with respect to their gender?
3. What are the levels of science process skills among senior secondary school students with respect to their academic stream?
4. Is there any significant influence of gender on science process skills of senior secondary school students?
5. Is there any significant influence of academic stream on science process skills of senior secondary school students?

6. Is there any significant relationship between science process skills and attitude towards science among senior secondary school students?
7. Is there any significant relationship between science process skills and attitude towards science among senior secondary school students with respect to their gender?
8. Is there any significant relationship between science process skills and attitude towards science among senior secondary school students with respect to their academic stream?

Research Methodology

Descriptive method of research was employed to answer research questions raised about the current status of the participants of this study. The main variable was senior secondary school students' Science process skills. Other variables were their attitude towards Science and demographic variables. The study focused on studying the respective influence of demographic variables on their Science process skills.

Sample

In the present study, a non-probability sampling technique, the purposive convenient sampling, was employed with a purpose of selecting a sample of senior secondary school students from two schools in Aligarh, Uttar Pradesh, India. The sample consisted of 140 students.

Tools used for Data Collection

Two tools, namely, Test of Integrated Science Process Skills and Physical Science Attitude Scale (PSAS)were used for collecting data online.

Test of Integrated Science Process Skillswas developed by Kazeni Monica (2005). It consists of 30 multiple-choice items, each item having four options. The maximum time limit of this test is 50 minutes. Each item is of one mark. Each correct answer is assigned one mark, whereas each wrong answer is assigned a zero mark. The test was scored according to this scoring key. The total marks scored by a student on this test were considered as his/her Science process skills score and were equal to the number of items answered correctly by him/her. Its content validity was established on the basis of judgements given by a team of subject experts. The internal consistency reliability of this test was found to be 0.81.

PSAS was developed Uzma Siddiqui (2016) to measure the students' attitudes toward Physical Science. It consists of 30 items and 5 dimensions, namely, enjoyment,

anxiety, confidence, career and importance of science. This scale is Likert-type scale and has five-option choices (Strongly Agree, Agree, Undecided, Disagree, and Strongly Disagree). Positively worded items were given a score of '5', '4', '3', '2' and '1' for '*Strongly Agree*', '*Agree*', '*Undecided*', '*Disagree*' and '*Strongly Disagree*' respectively. The scoring was reversed for negatively worded statements. The sum of the item scores on 30 items gave the total PSAS score for a particular student. The content validity of this scale was established by a panel of experts. Cronbach's alpha reliability coefficient of the total scale was found to be 0.86.

Statistical Techniques used for Data Analysis

Descriptive statistics (namely, frequency, percentage, mean and standard deviation) and inferential statistics (namely, independent-samples *t* test and Pearson product-moment correlation) were employed for analysing the quantitative data in accordance with the nature of variables involved and research questions of the study.

Data Analysis and Interpretation

Research Question 1: What are the levels ofScience process skills among senior secondary school students?

In order to answer this question, descriptive statistics (namely, frequency and percentage) were used. Frequency and percentage for the groups having high, medium and low levels of Science process skills respectively are presented in Table 1.Out of 140 students, 70 (50.00 %), 40 (28.60 %) and 30 (21.40 %) students were found to have high, medium and low levels of Science process skills respectively.

Table 1

Frequency and Percentage of senior secondary school students having high, medium and low levels of Science process skills respectively

Levels of Science Process Skills	Frequency (N)	Percentage (%)
High (21-30)	70	50.00
Medium (11-20)	40	28.60
Low (1-10)	30	21.40

Research Question 2: What are the levels ofScience process skills among senior secondary school students with respect to their gender?

Descriptive statistics (namely, frequency and percentage) were calculated for both genders separately to answer this question. Results are presented in Table 2.Out of 60 male students, 30 (50.00 %), 15 (25.00 %) and 15 (25.00 %) students were found to have high,

medium and low levels of science process skills respectively.Further, out of 80 female students, 40 (50.00 %), 25 (31.20 %) and 15 (18.80 %) students were found to have high, medium and low levels of science process skills respectively.

Table 2

Frequency and Percentage of senior secondary school students having high, medium and low levels of science process skills respectively with respect to their gender

Gender	Levels of Science Process Skills	Frequency (N)	Percentage (%)
Male	High (21-30)	30	50.00
	Medium (11-20)	15	25.00
	Low (1-10)	15	25.00
Female	High (21-30)	40	50.00
	Medium (11-20)	25	31.20
	Low (1-10)	15	18.80

Research Question 3: What are the levels ofScience process skills among senior secondary school students with respect to their academic stream?

Descriptive statistics (namely, frequency and percentage) were calculated for both academic streams separately to answer this question. Results are presented in Table 3.Out of 70 students enrolled in PCB stream, 35 (50 %), 20 (28.60 %) and 15 (21.40 %) students were found to have high, medium and low levels of science process skills respectively. Further, out of 70 studentsenrolled in PCM stream, 35 (50 %), 20 (28.60 %) and 15 (21.40 %) students were found to have high, medium and low levels of science process skills respectively.

Table 3

Frequency and Percentage of senior secondary school students having high, medium and low levels of science process skills respectively with respect to their academic stream

Academic Stream	Levels of Science Process Skills	Frequency (N)	Percentage (%)
PCB	High (21-30)	35	50.00
	Medium (11-20)	20	28.60
	Low (1-10)	15	21.40
PCM	High (21-30)	35	50.00
	Medium (11-20)	20	28.60
	Low (1-10)	15	21.40

Research Question 4: Is there any significant influence of gender on Science process skills of senior secondary school students?

In order to determine the influence of gender on Science process skills of senior secondary school students, an independent-samples *t* test was applied, the results of which are presented in Table 4. The results show that there was no significant influence of gender on Science process skills of senior secondary school students, t (138) = 0.78, p> .05. The mean Science process skills of female students (M = 18.95, *SD* = 6.17) was not significantly higher than that of male students (M = 18.10, *SD* = 6.47).

Table 4
Comparison of mean Science process skills scores of male and female senior secondary school students

Gender	N	Mean	*SD*	*df*	*t*	Sig. (*p*)
Female	80	18.95	6.17	138	0.78	.432
Male	60	18.10	6.47			

Note. t value is Not Significant at .05 level

Research Question 5: Is there any significant influence of academic stream on Science process skills of senior secondary school students?

In order to determine the influence of academic streamon Science process skills of senior secondary school students, an independent-samples *t* test was applied, the results of which are presented in Table 5. The results show that there was a significant influence of academic stream on Science process skills of senior secondary school students, t (138) = 3.91, p< .05. The mean Science process skills of students enrolled in PCB stream (M = 20.57, *SD* = 6.24) was significantly higher than that of students enrolled in PCM stream (M = 16.60, *SD* = 5.74).

Table 5
Comparison of mean science process skills scores of senior secondary school students enrolled in PCB and PCM academic stream respectively

Academic Stream	N	Mean	*SD*	*df*	*t*	Sig. (*p*)
PCB	70	20.57	6.24	138	3.91*	.000
PCM	70	16.60	5.74			

Note.* t value is Significant at .05 level

Research Question 6: Is there any significantrelationship between Science process skills and attitude towards Science among senior secondary school students?

Pearson Product-Moment correlation was used to determine the relationship between the Science process skills and attitude towards Science among senior secondary school students. Table 6 clearly shows that the correlation betweenScience process skills and attitude towards Sciencewas statistically significant, r (138) = +.677, p< .01 (two-tailed). Since the value of Pearson correlation coefficient was positive, this indicated a positive relationship between Science process skills and attitude towards Scienceamong senior secondary school students. Moreover, as per Cohen's guidelines (1988), since the value of Pearson correlation coefficient (r = +.677) fell in large range, therefore it revealed a significant and strong relationship betweenScience process skills and attitude towards Science.

Table 6
Correlation matrix of Science process skills and attitude towards Science for senior secondary school students using Pearson Product-Moment Correlation

	Science Process Skills	**Attitude towards Science**
Science Process Skills	1.000	.677**

Note.** Correlation is Significant at .01 level

Research Question 7: Is there any significantrelationship between Science process skills and attitude towards Science among senior secondary school students with respect to their gender?

The gender-wise results of Pearson product-moment correlation are presented in Table 7. For female students, the correlation between Science process skills and attitude towards Science was found statistically significant, r (78) = +.673, p< .01 (two-tailed). Similarly, for male students, the correlation between Science process skills and attitude towards Science was statistically significant, r (58) = +.681, p< .01 (two-tailed). Since the values of Pearson correlation coefficient for both genders was positive, this indicated clearly a positive relationship between Science process skills and attitude towards Science. Moreover, as per Cohen's guidelines (1988), since the values of Pearson correlation coefficient for both females (r = +.673) and males (r = +.681) fell in large range, therefore they revealed a significant and strong relationship between Science process skills and attitude towards Science.

Table 7
Correlation matrix of science process skills and attitude towards science for senior secondary school students with respect to their gender using Pearson Product-Moment Correlation

	Science Process Skills	Attitude towards Science
Science Process Skills		
Female	1.000	.673**
Male	1.000	.681**

***Note.** Correlations are Significant at .01 level*

Research Question 8: Is there any significantrelationship between Science process skills and attitude towards Science among senior secondary school students with respect to their academic stream?

The relationship between Science process skills and attitude towards Science among senior secondary school students with respect to their academic streamwas investigated using Pearson product-moment correlation coefficient. The results of correlation are presented in Table 8.For senior secondary school students enrolled in PCB stream, the correlation between Science process skills and attitude towards Sciencewas statistically significant, r (68) = +.726, p< .01 (two-tailed). Similarly, for senior secondary school students enrolled in PCM stream, the correlation between Science process skills and attitude towards Sciencewas statistically significant, r (68) = +.708, p< .01 (two-tailed).Since the values of Pearson correlation coefficient for both these groups was positive, this indicated clearly a positive relationship between Science process skills and attitude towards Science. Moreover, as per Cohen's guidelines (1988), since the values of Pearson correlation coefficient for PCB students (r = +.726) and PCM students (r = +.708) fell in large range, therefore they revealed a significant and strong relationship between Science process skills and attitude towards Science.

Table 8
Correlation matrix of science process skills and attitude towards science for senior secondary school students with respect to their academic stream using Pearson Product-Moment Correlation

	Science Process Skills	Attitude towards Science
Science Process Skills		
PCB	1.000	.726**
PCM	1.000	.708**

Note. Correlations are **Significant at .01 level

Conclusions and Implications

The findings of this study have revealed that only half of the sample had high level of Science process skills, while the remaining students were found to have either medium or low level of skills. This means that the level of Science process skills among senior secondary school students was not satisfactory. Similar results were obtained gender-wise and academic stream-wise respectively. Further, the results have indicated that gender had no significant influence but academic stream had significant influence on their skills. Furthermore, significant, positive and strong relationship was observed between Science process skills and attitude towards Science among senior secondary school students. Similar findings were obtained gender-wise and academic stream-wise respectively.

The poor performance of senior secondary school students on Science process skills in this study is of great concern and calls for an immediate and urgent action on the part of Science pre-service and pre-service teacher education and professional development programmes. Appropriate hands-on training programmes and workshops should be organised at regular intervals for in-service and pre-service school teachers, teacher educators and school students so as to develop conceptual understanding of Science process skills. School teachers and teacher educators should identify and diagnose the prior ideas and misconceptions of their respective students using appropriate performance and diagnostic tests. Moreover, teachers, counsellors and parents of students must provide suitable hands-on learning opportunities by creating real-life situations where they would be able to apply various skills. They should make it sure that students must carry out all the practical activities and experiments that are given in Science books. They should also be encouraged and advised to watch Science-related TV channels and TV programmes; read Science-related magazines, articles and news; and participate in Science-related co-curricular activities and projects.

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