AN EXAMINATION OF THE NATURE OF SCIENCE PRESENTATION IN HIGH SCHOOL CHEMISTRY TEXTBOOKS USED IN THE UNITED STATES AND INDIA

A Dissertation Presented to the
Faculty of the College of Education
University of Houston

In Partial Fulfillment
of the Requirements for the Degree

Doctor of Education

by

Ammani Krishnaswamy

December, 2014

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Abstract

The need for a scientifically literate society is essential to advance civilization and solve many global problems such as depletion of natural resources and carbon-based fuels, cure for life threatening ailments, famine, hunger, epidemics, and several other serious global problems. Scientific literacy is not restricted to factual knowledge of science but also extends to understanding science and how the scientific enterprise works (Clough, 2000). Therefore, learning about the “nature of science” has been considered as an important goal for both science teachers and students for more than 100 years.

Science textbooks play an important role in learning and delivering science content at all levels of science instruction (Lapointe, Mead, and Phillips, 1989; Stake and Easley, 1978; Weiss, 1993). This study sought to understand the extent to which science and the scientific enterprise (nature of science) have been represented in chemistry textbooks used in the United States and India. This cross-nation examination of science textbooks is important to the field of education and of science because textbooks serve as the principle teaching aids in science instruction in both countries.

Nature of science can be organized by four basic themes: science as a body of knowledge, science as a way of thinking, science as a way of investigating, and science and its interactions with society and technology (Chiapetta and Koballa, 2006). Further, an additional theme has been added: science and its interactions with engineering and technology. Together these five themes lead to the main question of the dissertation

study: What is the balance of the selected five aspects of the nature of science (knowledge, thinking, investigating, interaction of science with society, interaction between science, engineering, and technology with society) that are evident in chemistry textbooks used in the United States and India? To address the research question, the content analysis methodology was used in this study. To establish reliability and validity of the coding instrument, a preliminary study was conducted. The study involved analyzing random sampling of pages within five chemistry textbooks from the United States and chemistry textbooks from grades 10, 11 and 12 from India.

The dissertation study involved the analysis of five samples related to topics that include acids and bases, biological chemistry, chemical reactions, hydrocarbons, and the periodic table from chemistry textbooks that are used in the United States and India. Coding procedures for analyzing the random sample involved two sets of coders. One of the coders had previously analyzed physical science textbooks with regard to the nature of science and ethnic diversity (Brooks, 2008). The researcher was the second coder and is a community college instructor with ten years' experience of teaching chemistry at different grade levels. Both coders were trained to analyze the samples and the reliability of their coding checked before coding the chemistry textbooks. To check for inter-coder reliability, percent agreement and Cohen's kappa was calculated.

Results from the study indicate that science as a body of knowledge and science as a way of investigating as the two prominent themes in chemistry textbooks used in India and the United States. The knowledge component is represented by facts, theories, and laws and emphasizes information overload and rote memorization. Textbooks used in India and the United States present to students several investigative activities that are hands-on in nature. However, textbooks from India did poorly compared to chemistry textbooks used in United States with regard to the representation as to how scientists go about their work to establish chemistry. Only those samples related to the development of the periodic table represented the thinking aspect with regard to the nature of science from chemistry textbooks used in India. Textbooks used in India did poorly in the representation of interaction of science with society and the interaction between science, engineering, and technology. Even though engineering is a favored profession by choice of many science students in India, there is very little mention of this aspect of nature of science. The textbooks did not discuss any career opportunities available to students of science in the STEM fields. Textbooks used in the United States however, did emphasize the societal aspect of the nature of science and included discussions related to many career opportunities available in the STEM fields. Most chemistry textbooks used in the United States did poorly in the representation of the engineering and technology aspect of the nature of science. Holt, Rinehart & Winston and ChemComm did present a few examples to students that support the interaction of engineering and technology with science.

Textbooks are one of the primary instructional materials in science classrooms and play a dominant role in science teaching and learning. An imbalance in the representation of the five themes of nature of science suggests that students and teachers are being exposed to a poor understanding of the scientific enterprise from chemistry textbooks. Science educators, curriculum developers, and textbook publishers should make an earnest effort to provide a better balance of the five dimensions of the nature of science and to avoid portraying science as mainly a body of knowledge or as a way of investigating.

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Chapter I

Introduction

The impact of science and technology in everyday life is immeasurable. Climate change, depletion of natural resources and carbon-based fuels, cures for life threatening ailments, famine, hunger, epidemics, and many other serious global problems require scientific and political solutions. A survey conducted in July 2009 by the Pew Research Organization revealed Americans have a sustained interest in science and believe this field has an overall positive effect on their lives, both personally and as a society overall. However, only 27% of those surveyed believe landing on the moon was the greatest achievement of the United States during the 20th Century. Furthermore, a significant qualitative difference exists between public opinion and the beliefs of scientists on such controversial issues as climate change, necessity of vaccinations, and embryonic stem cell research. Only 13% of those surveyed state they follow science and technology news closely, while the vast majority was unfamiliar with newly emerging fields such as nano and biotechnology, geoengineering and synthetic biology – fields that may serve a substantial role in defining the future (Mooney & Kirshenbaum, 2009). Mooney and Kirshenbaum express concern in their (2009) publication regarding the scientific illiteracy of America writing, "the vast gulf between the world of science and that of the American public" exists (p. xiv). The authors attribute multiple causes for this existence including a poor education system, irresponsible and profit-driven media outlets, and attacks on the science field by the current political establishment.

Maienschein (1998) goes further stating that being "science literate" does not necessarily mean "scientifically literate." There is a significant difference between the two terms. While, science literacy focuses on gaining scientific and technical knowledge, scientific (with an "ic" at the end of this term) literacy emphasizes various ways of knowing and the process of thinking critically about the natural world. For example, understanding the production of nuclear energy through the design and operation of a nuclear power plant constitutes science literacy. Many in this field believe that being scientifically literate will empower people to make rational decisions, as if whether or not building a nuclear power plant near our city, as an alternative fuel source, is a good idea. Developing a scientific literacy requires a broader knowledge of science, the methods of science, and the nature of science. Alan Leshner, the Chief Executive Officer of the American Association for the Advancement of Science (AAAS), emphasizes the need for an understanding of science and how the scientific enterprise works, commonly referred to as the nature of science. Leshner urges the American public to become familiar and comfortable with the nature of science in order to solve many of the problems and issues of everyday life and to be able to evaluate critically true scientific claims (Leshner & Perkins-Gough, 2007).

The National Science Board, which is the policymaking body of the National Science Foundation, is optimistic in its view that the United States remains the global leader in supporting research and development in the fields of science and technology. However, the board cautions the leadership status of the United States soon is in jeopardy from Asian countries. Now, it is imperative to re-examine the long-held science and technology assumptions by the United States in the global world. As cited in the 2005 work of Friedman, the 2004 president of the AAAS, Shirley Jackson, explains, "a quiet crisis" is brewing. The quiet crisis is a steady erosion of scientific and technology base of America, which is a source of American innovation and quality of life (Friedman, 2005). Competitor countries like China and India are quickly closing the qualitative distance in the field of science and technology.

The post-Sputnik era saw an increase in the number of students enrolling in the fields of science and engineering. However, in later years, fewer people were excited by the space program and space exploration and, as a result, enrollment in science and technology programs began to decline. Recently, a domination of standards-based testing and accountability in the American public school system has all but left science behind. The No Child Left Behind Act of 2001 (NCLB) uses student test scores on standardized assessments as the primary source of measuring of quality of a school campus and school districts (Ravitch, 2010). Test scores in Reading and Mathematics became the principle measure of school quality and an important variable in judging the academic successes of students and schools while at the same time determining the quality of teachers and principals. Schools, as a responsive action, are devoting considerable amounts of class time in an effort to prepare students in these two testing areas. As a result, the study of science has received much less emphasis than reading and math. Under the terms of NCLB, school campuses not demonstrating adequate annual student progress, such as a general proficiency in Math and English, by 2014 are subject to arduous sanctions imposed by the Federal government.

Ravitch is critical about the standards-based testing, and questions how this technocratic approach to school reform that measures success in two skill-based subject areas is able to strengthen the nation to compete on an international scale. Specially, the fields of science and technology have higher concerns. The performance of the United States in comparison to several other countries has been continually below average according to Trends in International Mathematics and Science Study (TIMS, 2011). The vast number of U.S. jobs requiring science and engineering knowledge will continue to grow, yet there has been a steady erosion of qualified science and engineering graduates to fill these positions. However, at the same time the number of job seekers applying for these positions from other countries also will decrease because of imposed U.S. security restrictions and intense global completion (Friedman, 2007). Hence, it is crucial for the country to re-evaluate its goals in the fields of science and engineering and to redefine its educational policy if the nation hopes to preserve its position in the emerging global economy. Thomas Friedman cautions all Americans of this fact by writing:

> Young Chinese, Indians, and Poles are not racing us to the bottom. They are racing us to the top. They do not want to work for us; they don't even want to be us. They want to dominate us – in the sense that they want to create companies of the future that people all over the world will admire and clamor to work for (2007, p. 265).

Need for the Study

It is a given that textbooks are the primary teaching aids in most science classrooms at all levels of classroom study (Lapointe, Mead, and Phillips, 1989; Stake and Easley, 1978; Weiss, 1993). An evaluation conducted by Project 2061 found that American science textbooks generally covered topics at a superficial level, were focused heavily on vocabulary keywords and technical terms, yet little was provided connecting the cognitive thinking processes of students and their prior knowledge about the subject matter. In general, these curriculum materials failed to connect integral scientific ideas to real-world phenomena. They also failed to help students overcome their misconceptions concerning the field itself (Kesidou & Roseman, 2002; Stern & Roseman, 2004). Several studies conducted analyze the extent to which science and the scientific enterprise (nature of science) have been represented in science textbooks.

A procedure for conducting a content analysis of science textbooks developed by Chiappetta, Fillman and Sethna in 1991 is considered a useful tool in analyzing the extent to which the nature of science is included in science textbooks. This study focuses on comparing science textbooks of the United States and those in India using the inclusion of nature of science as a basis. This cross-nation comparison of science textbooks is important to the field of education and of science because textbooks serve the principle teaching aids in science instruction in both countries.

Purpose of the Study

The purpose of the dissertation study is to analyze the extent to which five themes of the nature of science are represented in science textbooks from the United States and India, and to compare chemistry textbooks from the United States and India based on five themes of nature of science, which are: (1) science as a body of knowledge; (2) science as a way of thinking; (3) science as a way of investigation; (4) the interaction of science on the society; and (5) the interaction of science, engineering and technology with society. By examining the themes and content found in American and Indian science textbooks, it is possible to develop an understanding of how science and the scientific enterprise is presented in one of the most important teaching resources.

Research Questions

1. What is the balance of selected five aspects of nature of science (knowledge, thinking, investigation, interaction of science with society, interaction between science,

engineering, and technology with society) in high school chemistry textbooks used in United States?;

2. What is the balance of selected five aspects of nature of science (knowledge, thinking, investigation, interaction of science with society, and interaction between science, engineering, and technology with society) in high school chemistry textbooks used in India?; and

3. What are the similarities and differences in the representation of the selected five aspects of nature of science in chemistry textbooks used in the United States and India?

Chapter II

Education In India

Pre-Independence

India is renowned for a rich cultural history dating back to several millennia. Knowledge was preserved in earlier times by oral communication from one generation to another. Residential schools, also known as *gurukuls*, were set up where the pupils resided with the teacher or the *guru* and the learning process was accompanied by assisting the guru with household chores. Teachers charged no regular fee and their duty was to teach students irrespective of their social and economic differences. Traditionally, the teacher in India has been held in high esteem. The teacher is viewed as the revered individual who is responsible for facilitating the intellectual growth of the student and leading him from darkness toward the illuminated path of knowledge. A belief that was established in ancient India is still recognized and both teachers and the teaching profession are conferred the same high degree of respect even today. Sanskrit, the oldest language in the world, was the language of the scholarly. The same language appeared in both educational and religious texts (Kuppusamy, 2009; Gupta, 2007).

The foundation for modern higher education was laid when the British colonized India in the middle of the 19^{th} Century. William Adam, a missionary and a civil servant of the colonial empire spent three years (1835-1838) surveying the educational system. Adam's report (1835) bears testimony to the quality of education during the pre-colonial era of the subcontinent. Adam observed a significant diversity in the schools he visited and noted that the medium of instruction in these regional schools was vernacular. A single teacher taught at each school, funded by the local property owners, and a small fee charged to each student. These indigenous schools were limited in terms of the variety of courses taught and the number of years spent in mastering a specific course. The students were not awarded a degree or a certificate and only their accomplishments bore testimony to their proficiency in a particular subject.

The vernacular schools trained the students for a specific career. Schools taught in Bengali and Hindi focused on writing and reading skills, accounting, agriculture and commerce. Persian schools taught in Urdu, trained their students to master the art of calligraphy, poetry and law. Schools taught in Sanskrit prepared their students to be teachers, lawyers, astrologers, literature specialists and logicians. These indigenous schools provided education to all students irrespective of caste or creed. No specific schools were set up for women but they had the option to learn to read and write (Di Bona, 1981).

However, Adam, in his reports expressed support for the indigenous schools, their growth and progress was hampered by excessive taxation by the British government and severe famine and drought conditions in the country. The famous minute of Thomas Macaulay in 1835 established English as the official government school policy. In 1854, the Woods Dispatch mandated the need of educational credentials (primarily in English) for securing jobs in the colonial government. Social activists such as Raja Rammohan Roy advocated the need for Western education in order to fight social evils such as sati, child marriage, caste discrimination, and dowry (Nilekani, 2008).

The first three universities established were in Bombay (now Mumbai), Calcutta (now Kolkata) and Madras (now Chennai) in 1857 (Jayaram, 2006). The working of these universities was modeled after the University of London, established in 1836. The main function of these universities was to conduct examinations and award degrees while teaching was conducted in local affiliated colleges. The English language became the exclusive medium of instruction in higher education. The content was partial toward the humanities while science and technology received little attention.

The British favored Anglicized orientation of higher education. Uniform courses were established which were biased toward languages and humanities rather than science and technology. There was not enough money allocated in the budget to establish numerous schools and colleges. However, the British were keen in offering Western education in hopes of creating a class of educated Indians who would owe their allegiance to the British sovereignty. Contrary to the British beliefs, the Western educated Indians saw themselves as the voice and emissary of social emancipation.

Gupta (2007) points out that the textbook-centered pedagogy that continues to dominate the educational system in India is a legacy of the British colonial era. The British propagated and influenced the growth of Western education mainly to prepare Indians to work at the lower and middle levels of colonial administrative work. Schools, which sought government aid, had to adopt the syllabus and textbooks prescribed by the colonial government. The examinations designed by the British administrators were based on the content of these textbooks. Employment in the public services was conditional to passing these examinations and demonstration of command and mastery of the English language and literature, as well as the British customs and etiquette. The rote memorization and examination-based system of education became instrumental in filling up the low-level clerical and administrative positions. It is ironical that it has been more than 60 years since the British evacuated India but the rote memorization and examination-based is still strongly rooted in the Indian education system.

As the bitter struggle for freedom of India ensued and heightened in the early twentieth century, a resolution was passed in 1920 to set up schools that offered a "Nai Talim" (or new education) form of education to the masses. Mohandas Gandhi, pioneer of the Indian freedom movement, proposed this idea. Gandhi wanted schools to focus on teaching real-life skills using village arts and crafts for boys and domestic science for girls. The teaching was focused to be more student-centered. The medium of instruction was that of the local or regional language. He wanted the children to embrace love and respect for physical work. Gandhi strongly believed that the "Nai Talim" schooling would foster the attitude of truth and a sense of nonviolence among the youth. This form of education hoped to create a population that was self-sufficient only within the village communities. However, efforts in establishing these technical schools did not succeed as the British government did not recognize these schools. The rewards for a British style education were considerable and more attractive (Mililani, 2008; Sharma, 2002).

Toward the end of the British rule, the establishment of approximately 20 universities and 496 affiliated colleges catering to 241,369 students occurred throughout the country. However, the state of higher education in the country was "anemic, distorted and dysfunctional" (Jayaram, 2006, p. 748).

Post-Independence

When India declared independence against the colonial rule in 1947, the social, economic and political scenario of the country was unsettled due to recent partition of the country. The educational system of the country was also in deep waters with literacy rates as low as 12% and enrollment in schools and colleges ranging to 40% (Nilekani, 2008). The limited access to quality education held back the country from significant social and economic growth.

The first Education Commission Report was released in 1954 with the goal of framing the national education policy. The report stressed the need for education especially for promoting economic growth and development in the country. Though dynamic political leaders and educational secretaries spearheaded the movement, not much was achieved in terms of retaining enrollment or even achieving higher literacy rates.

The first prime minister of the country, Pandit Jawaharlal Nehru envisioned a secular democracy and stressed the need for education and industrial development, which were seen as crucial tools to unite a country which was split on the basis of caste, creed, wealth and religion and was not healed much even after independence from the imperial rule. Post-independence, school curricula encompassed themes of national pride and unity, emphasizing the fact that different communities can coexist peacefully after attaining freedom from the imperial rule.

Drawing on Nehru's dreams and vision of a united and secular country, the government established the Kothari Commission in 1964, named after its chairperson P.S. Kothari. The central theme of the commission was to formulate a coherent education policy. The core educational ideas of the commission were to increase productivity, develop social and national unity, consolidate democracy and promote social, national and spiritual values. The commission promised free and compulsory education for all children until age 14 in government established schools across the country. In addition, it proposed the introduction of the three-language formula in government schools. The commission promised equality of educational opportunities for all citizens in order to overcome regional, tribal and gender imbalances. The commission strongly advocated the development and prioritization of science education and research instead of social sciences and commerce. It stressed on the need to eradicate illiteracy and provide adult education and firmly believed that education is the primary medium to industrialize the country in the 20^{th} Century (Lall, 2005).

The three-language formula was proposed by the Education Commission in 1964 and soon became widely accepted by the nation. A school-going child in the Indian sub-continent was expected to study (a) the mother tongue or the regional language of the state; (b) the official language of the Union (Hindi) or the associate official language of the Union (English); and (c) a modern Indian or foreign language not covered under (a) or (b) and not used as the medium of instruction. Gupta (2007) explains that despite the three-language implementation efforts there is a marginalization of people who do not speak the above languages. Going further, the language barrier specifically pertained to those belonging to tribal or indigenous populations.

Several developed countries and many developing countries have strived successfully to remove children from the labor force. Modern states believe that employers should not employ children and parents have to send their children to school. Compulsory primary education is viewed as a legal duty. However, in India primary education is not heavily mandated and child labor is not considered illegal.

Employed children take care of cattle and other farm animals, collect firewood, work in fields, in cottage industries, tea stalls, restaurants, collect trash for resale and some are forced to enter prostitution. Children are viewed as an economic asset to the poor parents. The income they bring in to the household is usually not very significant but parents need their help in maintaining and sustaining a livelihood. Indian law prohibits child labor in factories but not in cottage industries, family households, restaurants and agriculture (Nilekani, 2008).

Indian view of social order, particularly notions about respective roles of upper and lower social strata has prevented significant action against child labor. Education has been used as a means of maintaining differentiation among social classes. Primary education for the poor children has been widely rejected on the basis that it does not prepare them for unskilled work force, which deemed as the career choice for the poor. In addition, villagers want urban jobs, especially employment in the government that provides income and financial security. The school system increases competition for white collared jobs creating a population of educated unemployed youth.

The hierarchical caste system in India has further aided growth of child labor. India has not been successful in banning child labor altogether, however, the constitution contains a number of provisions intended to protect children, including a categorical ban that declares "no child below the age of fourteen years shall be employed to work in any factory or mine or engaged in any hazardous employment" (Indian Const. art. 24).

As per the Global Report on Child Labor published by the International Labor Organization in 2009, child labor activity in the age group 5-14 years is 5.1% in Latin America and the Caribbean Region while 18.8% was recorded in the Asia-Pacific region. The activity rate for children in India, as per 2001 census was 5%. The government has accepted the harsh reality of child labor but has taken steps in recent years through programs and initiatives of Non- Governmental Organizations to improve working conditions for child laborers and also provide work based education to these children. One such program established by the government is the National Child Labor Project (NCLP) in 1988. Under the NCLP Scheme, children are withdrawn from work and placed in special schools where they are provided with bridging education, vocational training, mid-day meal schemes, stipends, health care facilities and finally mainstreamed to the formal education system. At present, there are around 10,000 NCLP schools and 520,000 children have been mainstreamed to regular education. The International Labor Organization launched another program called the International Program on elimination of Child Labor in 1991. India was one among the first few countries to join this program to create awareness for securing elimination of child labor.

However, the government focused on building infrastructure rather than attending to toward training, educational achievements and performance measurement concerning teachers. The government has and continues to spend enormous amounts of money in education, however, the quality of education has been dismal. As a result, the number of illiterates continued to grow and very little teaching took place in government schools. As writer Amit Verma (2007) succinctly puts it, “the state has funded schools, not schooling. For India’s sake, that must change.”

Even though India has a large number of students from rural and poor households who are out of school, at the same time the nation also has the largest pool of trained and skilled workers in the world. India has three types of schools – public or government schools, private-aided, and private-unaided. Public schools are those owned and run by the government. Private-aided schools secured funding from the government but managed privately. Private-unaided schools both managed and funded privately

(Chudgar & Quin, in press). There are a large number of government schools throughout the country, and an extensive system of private schools, especially in urbanized areas. Traditionally, students from a low socio-economic background opt for government schools, which offer either free or subsidized education. The middle class and upper middle class population usually affords private schools, which charge a higher tuition.

The educational system in India is driven by a rigid examination system that serves as the primary means of assessment of students. Government organizations such as the National Council for Educational Research and Training (NCERT) design the national curriculum that becomes translated into a prescribed syllabus and a set of textbooks for each grade level. A recommendation of the syllabus and textbooks occurred to the 42 examination boards of the country. The principal examination boards include Central Board of Secondary Education (CBSE), which is the largest educational board in the world at the operational level, Indian Certified School Examination (ICSE), State Board of Examinations (SBE) and the Matriculation Board of Examination (MBE). Most urban schools usually are affiliated to the CBSE or ICSE board of examinations. Students are assessed at the end of each academic year for the content they have mastered from the textbooks they have studied during the academic year. The states also play an independent role in defining the educational details offered in schools through the State Boards of Education. All the states and the union territories of the country have adopted a uniform 10 + 2 educational system. Used at government schools at the primary level, regional language dominates as the medium of instruction. However, the English language is the medium of instruction in all private schools.

In all government and private schools throughout the nation, the respective State Boards of Secondary and Higher Secondary Education hold public examinations at the end of grades 10 and 12. Promotion to grade 11 and high school graduation is dependent on the scores obtained at the public examination. After grade 10, examination students have the option of choosing from two tracks of postsecondary education. The first track consists of vocational, technical and semi-professional courses leading to a variety of certificates and diplomas. The duration of these courses may be between 1 year as in the case of industrial training and teacher education to three years, as in polytechnic schools. The second track is the academic track of two years duration (grades 11 and 12) and it is a prerequisite for collegiate education (Jayaram, 2006).

As previously mentioned the national curriculum is designed by the government organization NCERT and implemented by the CBSE. The academic structure for schools affiliated to the CBSE board of education is as follows (Gupta, 2007):

> Learning areas 1 and 2: Two languages (in addition to the medium of instruction). Out of the two one may be Hindi or English (or both) and the second language is chosen from Assamese, Bengali, Gujarati, Kashmiri, Kannada, Marathi, Malayalam, Manipuri, Oriya, Punjabi, Sindhi, Tamil, Telugu, Urdu, Sanskrit, Arabic, Persian, Limboo, Lepcha, Bhutia, Nepali, Tibetan, French, German, Portuguese, Russian, and Spanish;
>
> Learning areas 3, 4 and 5: Three electives to be chosen out of mathematics, physics, chemistry, biology, engineering drawing, economics, political science, history, business studies, accountancy, home science, fine arts, agriculture,

computer science, sociology, psychology, philosophy, physical education, music and dance;

Learning area 6: General studies;

Learning area 7: Work experience; and

Learning area 8: Physical and health education.

Vocational stream of studies offers students electives such as typewriting in English, stenography in English, typewriting in Hindi, stenography in Hindi, marketing, consumer behavior and protection, storekeeping, and store accounting.

The second and third language is required only until grade 10 and not after. Students who complete grade 10 examinations are expected to choose one of the following academic streams for grades 11 and 12. The academic streams include the science stream (medical or non-medical), commerce or humanities.

The science stream includes English, chemistry and physics as the mandatory subjects. Students may opt to choose one of the following:

1. Medical stream within which biology is required, and the fifth course can be either math or psychology; or

2. Non-medical stream within which math is required, and the fifth course can be either computer science or economics.

The commerce stream includes English, accountancy, business studies and economics as the mandatory courses. The fifth course may either be math or computer applications.

The humanities stream includes English, psychology and economics as the mandatory courses. The fourth course is an option between history and political science and the fifth course may be chosen from math, computer science application, fine arts (graphics or painting), or geography. In addition, expected student participation during physical education occurs from all streams.

On successful completion of grade 12 examination students may pursue a degree course (such as bachelors of arts, commerce or science) of three years duration or a professional degree (such as bachelors of medicine and surgery (MBBS), bachelors of engineering or technology (BE/B.Tech) or bachelors of nursing (BSN)). These professional courses may range from anywhere between four to five years in duration. Competition for admission to these professional courses is very stiff and students usually opt for private tuitions or "coaching classes" outside of school, which helps them, had better prepare to qualify for these programs. Admission to these programs is based on the grades of class 12 examinations as well as entrance examinations held for these professional courses. Admission to government professional programs is preferred compared to private institutions that charge high tuition rates. Individual teachers hold the private "coaching classes" or groups of teachers and institutes often advertise in newspapers claiming credit for the success of students (Jayaram, 2006).

One of the biggest challenges of the Indian education system is that even the poor and illiterate parents have begun abandoning the government schools (Nilekani, 2008). One of the main reasons for abandonment of government schools has been the three-language policy introduced in these schools post independence. The medium of instruction has been that of the regional language of each state and all subjects are taught in the regional language. Students are also taught English and Hindi, but to a limited extent. Middle class parents prefer to educate their children in English medium schools, as they strongly believe that this will open up more avenues in the job market.

Other reason cited for disinclination toward government run schools has been teacher truancy. A study conducted by Kremer, Chaudhary, Rogers, Muralidharan, and Hammer (2008) shows that India demonstrates the second highest average absence rate among eight other countries. The study covered 20 Indian states, representing 98% of the population, or roughly one billion. Unannounced visits occurred at approximately 3,700 schools. The study focused on government run primary schools, rural private schools and private-aided schools located in villages.

The authors observed that absence rates of teachers were high in low-income states. Moreover, even if teachers were present, only 20-25% was actively engaged in teaching duties at the school. Teacher truancy was not motivated by salary levels; however, infrastructure of the school was a major factor. Other conditions that were identified that affected the motivation of teachers were the location of the schools and teaching conditions. Many teachers preferred less remote schools and were less likely to be absent from schools closest to a road. Schools that had teachers teaching multiple grades simultaneously had exhibited higher rates of teacher absence. Inspections of government schools rarely occurred. The authors observed that schools that were inspected showed a slightly lower teacher absence rate. Schools located in rural and less educated communities did not have much parent involvement to complain about teacher absences. The authors feel that local community involvement could drive the formulation of Parent Teachers Association and help nurture more conscientious teachers and headmasters.

Though private teachers were paid wages lower than public school teachers were, they reported a lower teacher absence rate. Private school teachers had greater chances for dismissal for being absent or tardy compared to government run schools. Advocates of private schools have observed the growth of these schools, particularly in areas where government schools have functioned poorly (Tooley, 2002). The flourishing of these schools demonstrates how the private sector has been able to reach the under-privileged and poor where the government has failed.

The private schools in the country are a hybrid-mix ranging from Italian-origin Montessori schools, church affiliated schools, single sex convents, schools run by private trusts such as the Hindu missions. "Central" schools were set up for children of central government employees, and Sainik schools were set up for children of military personnel. Private school classification is as a "recognized" or an "unrecognized" school. Government recognition is an official stamp of approval required for private schools and this stamp of recognition is obtained by fulfilling a wide variety of conditions. The existence of large numbers of unrecognized schools suggests that parents do not take the recognition seriously and prefer to enroll their children in private schools than in government run schools.

Kingdon (2007) observes that the growth of private schools has dramatically accelerated over time, being greatest at the primary level and progressively smaller at the middle and high school level. In urban India, private schools absorbed 56.8% of all the increase in total primary school enrollment in the period 1978-1986. While during the period of 1986-1993 absorbed 60.5% and 95.7% was absorbed between 1993-2002. Kingdon (2007) credits that 96% of the total increase in urban primary enrolment was due to the growth of private schooling which also signals inequality of educational opportunity available to parents. According to the Annual Status of Education Report (2009) published by the non-governmental organization Pratham, 14 out of 19 states showed a rise in private school enrollment. A few states such as Orissa, Bihar and West Bengal have shown a decline of private school enrollment. The ASER Report (2009) also indicates, in classes 1-5, the percentage of children who could read at least class 1 level text was 43.6 in government schools and 52.2% in private schools. Students in private schools had an 8.6% advantage. The study conducted does not take into account the different factors that might affect the learning level of the child. The educational background of the mother and supplemental help offered at home in the form of paid tuition or by family members have led to the improvement in the learning outcomes of the students. If these factors positively correlated by going to private school, their impact will result in an enhanced learning outcome of the students.

Indian states have tackled the challenges of the education system in their own ways and have obtained varied results. Several proposals are financed by the country's Department of Education and include mid-day meal schemes to primary schools, teacher education, vocational education and efforts to increase female literacy. The states that did succeed in making progress in school education are the ones that addressed the challenges of educating the poor first. The southern states of the country have had more success in this aspect compared to the northern states. *Pallikudams* and *kudipallikudams*, equivalent of kindergarten and primary schools were established with an emphasis to provide basic education in the southern states. The state of Tamil Nadu established the midday meal scheme, provided free lunch, uniforms and textbooks to schoolchildren attending government schools, and resulted in an increase in enrollment in government schools.

Another program that has gathered momentum and publicity in recent years has been the *Sarva Shiksha Abhiyan* (SSA) – "Campaign for Universal Education." This is a new scheme sponsored by the central government and obtains funding through a 2% "primary education" tax, which was implemented in 2004 and a 1% tax for secondary education implemented in 2006. The goal of this program is to universalize elementary education (grades 1-8) by the year 2010. The program provides funding to states to enroll out-of-school children. It also funds civil works, salaries of additional teachers so that teacher-student ratio of 1:40 may be maintained, fund bridge courses for dropouts, in-service training for teachers, and provide grants for supplies and teaching materials. This project is not restricted to improving infrastructure but also aims in providing quality education to students enrolled in government schools (Kingdon, 2007).

India continues to face several tribulations as far as her education system is concerned. The country battles the responsibility of providing free, accessible and quality education to all the children and maintaining skilled, English speaking workforce that will continue to contribute to the global economy of the flat world.

Science, Technology and the Indian Society

Before India became independent from the colonial rule on August 15, 1947, the growth of science and technology was limited. The colonial empire laid an over-emphasis on the training of Indians in English language, literature and morals. This resulted in an overcrowding for jobs in the legal, judicial and administrative professions. The main aim for offering minimal medical and technical education to the inhabitants was to train them as assistants and sub-assistants under European medical officers and engineers. The colonial empire also wanted to extract the natural resources using local labor and did not see it necessary to train the inhabitants in science and technology. Offering science education as a means for intellectual growth and progress was not a part of the British plan (Sangwan, 1990).

There were very few institutions devoted toward scientific research and growth. The only significant agency established during the British era was the Council of Scientific and Industrial Research (CSIR) in 1942. Some of the leading figures in scientific research during pre-independent India include Sir Jagadish Chandra Bose (1858-1937), who discovered radio propagation in 1905; Sir Chandrasekhara Venkata Raman (1888-1970), who discovered the Raman scattering effect; Satyendra Nath Bose (1894-1974), who developed the Bose-Einstein statistics; and Meghnad Saha (1893-1956), who worked on stellar physics.

Though the British had established universities and colleges around the country, very few science courses were taught at these universities and colleges. The two major toward institutions devoted toward scientific research and growth include the Indian Institute of Science in Bangalore, and the Indian Association for the Cultivation of Science in Kolkatta. Both these research institutes were funded by generous donations by Indian philanthropists Jamshedji Tata and Mahendralal Sirkar respectively. Homi Bhabha (1909-1966) founded the Tata Institute of Fundamental Research in Mumbai in 1945 with a generous donation from the Tata Trust. Bhabha stressed the need to develop a world-class research community in India. The atomic energy program had its birth in this institute.

After independence, Jawaharlal Nehru, the first Prime Minister of the country, made science and technology an integral part of the development of India. He saw the need for contribution of science in order to break the shackles of poverty and disharmony left behind as scars by the Imperial rule. His scientific policy resolution, proposed to the Parliament in 1958, affirms the support of the government to science and technology so that the country may prosper in years to come (Rao, 2008). During the tenure of Nehru as Prime Minister of the country, the premier Indian Institutes of Technology (IITs) were established in the cities of Mumbai, Delhi, Kanpur and Chennai. Until date, IITs are considered to be world-class institutions and engineering graduates who have made a name for themselves in the global market. India has respected and recognized the importance of international cooperation in science and technology. Such cooperation played an important role is designing, planning and setting up the IITs. The establishment of each IIT occurred with the help of foreign collaboration, funding and training. United Kingdom helped in the establishment of IIT/Delhi, the Soviet Union with IIT/Mumbai, West Germany with IIT/Chennai, and United States with IIT/Kanpur.

The government has been active in its support toward the growth of science and technology both at the national and at the international level. With the help of the National Committee of Science and Technology (NCST), formed in 1971, the government has been able to come up with new ways to incorporate science and technology in socioeconomic planning. Some of the achievements of NCST include establishing the Department of Science and Technology and the Science and Engineering

Research Council to fund basic research.

India had to import large quantities of food grains in the 1960s to support its vast population. A green revolution was ushered in, and breakthroughs in the field of agriculture helped grow and preserve food supplies even during inclement weather conditions. The food supply issue that had plagued the country for several years was resolved in less than a decade.

The Indian Space Program began in the early 1960s as a project of the Department of Atomic Energy and one of the heavily funded programs by the Government. Vikram Sarabhai, a scientist with humble beginnings, pioneered the Indian Space program. Sarabhai was enthralled by science and technology as a child living his dreams of establishing a space program as an adult. In 1972, the Space Commission (policymaking organization) and the Department of Space (the administrative machinery of the government) supported the Indian Space Research Organization (ISRO). ISRO led the launch of a series of satellites for communication, meteorology, broadcasting, natural resource surveys, education, cartography, telemedicine and identifying ocean resources. In 1976, ISRO used the American Application Technology Satellite (ATS-6) for Satellite Instructional Television Experiment (SITE) and broadcasted a series of educational TV programs in different languages. The programs focused on issues concerning health, family planning, and agriculture to more than 2500 villages spread over six states. SITE proved to be a successful experiment using space technology. The first satellite launch in India in 1975, Aryabhata, was from Soviet Union on April 19, 1975 and several more have been launched from the Sriharikota base (Narasimha, 2008).

EDUSAT (Educational Satellite) is the first Indian satellite built exclusively for serving the educational sector was launched on September 20, 2004,into a Geosynchronous Transfer Orbit. The satellite was launched to meet the demands of educating the population of rural and remote locations using a distance education approach. Since post- independence, there has been a surge in the establishments of urban schools, colleges and universities and steady rise in enrollment. However, rural and remote areas lacked adequate infrastructure and good teachers affecting the quality of education. Satellites can establish the connectivity between urban educational institutes with adequate infrastructure and the large number of rural and semi-urban educational institutes that lack quality infrastructure. Satellite systems have been used to facilitate the dissemination of knowledge on important aspects such as health, hygiene and personality development. The configured satellite includes an audiovisual medium, employs a digital interactive classroom and uses a multimedia system. The scope of the EDUSAT program was planned in three phases including national beam coverage, regional beam coverage and several pilot projects. National beam coverage involves satellite coverage for Indira Gandhi National Open University and National Council for Educational Research and Training where terminals are provided for secondary education and teachers training. Regional beam coverage provides educational opportunities to connect schools and colleges in the rural areas. The successful launch of EDUSAT and its commissioning has provided a great impetus to countrywide distance education (Indian Space Research Organization, 2005).

The most striking development and progress in India can be attributed to the Information Technology (IT) industry. Computers have rapidly affected all lifestyles and developing the right software has become a global challenge. India has been one of the key players in the global IT industry with a huge reservoir of technical talent with excellent software and hardware skills. The role of India and contribution to the field of Information Technology (IT) is creditable but the journey to reach this point was arduous. When Pandit Jawaharlal Nehru became the Prime Minister of independent India, he sent his team of economists to Soviet Union. The economists were deeply impressed with the socialistic view of the Soviet economy that they decided to adopt the same system back home. Planning commissions were set up to manage and control every policy and issue while private sector took a back seat and fell under this wall of regulation. Throughout the 1960s and 1970s, the Indian government viewed the advent of computers as a threat to the working class and computer imports were heavily mandated. Computerization suffered heavily until the early 1980s. Rajiv Gandhi, the Prime Minister of the country was ahead of his times in the use of technology. The Prime Minister strongly supported the growth of information technology, but faced building oppositions both from his own government and from the opposition parties.

The government owned infrastructures from 1947-1991 almost bankrupted the country in the early 1990s. Dr. Manmohan Singh, the finance minister (and now the Prime Minister) of the country decided that the only way to save the sinking economy was to open the economy to foreign investment (Friedman, 2005). At the same time, the rest of the world was facing a PC network revolution. The free market and the PC network revolution helped many foreign companies to establish trade relations with India thus forcing India to step quickly into the world of Information Technology (IT). IT firms such as Infosys, Wipro, and Tata Consultancy Service (TCS) propelled the Indian economy and industry into global view. According to Nandan Nilekani (2008), former

CEO of Infosys, Indian IT firms absorbed global management practices and standards that enabled "Indians to dream the dream of income growth and class mobility that had caught the imagination of the working class in the United States and Europe throughout the twentieth century" (p. 101). The growth of IT industry provided jobs to people helping them aspire and achieve standards of living their parents have never experienced.

According to Mashelkar (2008), the platform for the growth and progress of science and technology in India rests on four main pillars, namely: techno-nationalism, inclusive growth, techno-globalism and global leadership. India ranks one among the few nations in the world that has made a mark in the field of space science and technology. This includes the design and construction of satellites and launch vehicle technology. Space technology has been applied to address several national needs such as communication, meteorology, broadcasting and remote sensing.

The launch of the Center for Development of Advanced Computing (C-DAC) in 1987 marked its entry in supercomputing. Though in the late 1980s, the Soviet Union offered supercomputers to India, the offer was declined. In 1991, India developed its first supercomputer PARAM 8000 based on parallel processing architecture using transputers. The development of several other supercomputers such as Flowsolver by National Aerospace Laboratories (NAL), ANUPAM by Bhabha Atomic Research Center (BARC), and ANURAG by Defense Research and Development Organization (DRDO), has established India as one of the key players in the field of supercomputing.

The three types of technology which have aimed in improving the quality of life for the economically under-privileged include process, product and enabling technologies (Mashelkar, 2008). Process technologies have resulted in increasing efficiency and improving the quality of resources, particularly in agriculture, animal husbandry, and mining. Product technologies have improved the quality and cost of products making them affordable to the common public. Enabling technologies have facilitated coordination, information sharing and exchange between buyers and sellers, thereby reducing transaction costs.

The Indian Council of Medical Research (ICMR) and the Indian Council of Agricultural Research (ICAR) have financially supported research at universities and network projects involving scientists and industrial research centers.

India is one of the principal exporters of essential oil and its products. This has generated strong employment at the bottom of the pyramid (Mashelkar, 2008). This achievement has been made possible by the concerted efforts of the research institution, Central Institute of Medicinal and Aromatic Plants (CIMAP). Another example is the leather industry, which has created millions of jobs throughout the pyramid. The Leather Technology Mission (LTM), aimed at creating a technology driven development integrated several sectors both private and public with the support of the CSIR. The inclusive growth is not limited to the support offered by government funded research and development but also extends to the private sectors. A well-designed public -private partnership has been beneficial in providing affordable products such as medications at a relatively lower costs to the economically under-privileged. A classic example is the access to cost-effective anti-AIDS therapeutics compared to the price set by multinational companies.

Some educational institutions have also participated actively in supporting inclusive growth. The Telecommunication and Networking group (TelNet) at the Indian

Institute of Technology in Chennai have developed ICT solutions that deliver a menu of services such as healthcare by telemedicine, agricultural consulting via the Internet, education, communication, banking, entertainment and e-governance. Early experiments reveal that ICT solutions may serve as powerful tools for revitalizing the quality and standards of living of rural India. The government established the National Innovation Foundation with the key objective of documenting grass-root innovations and providing support for improvement of innovative products by collaborating with several research and development institutions (Mashelkar, 2008).

The Indian Science Report (Shukla, 2005) recognizes the need for science education for the country to be a key player in the competitive global market. The report emphasizes that scientific knowledge is central to the country's productivity growth, whether in manufacturing, agriculture, or other services and may serve as a key factor in determining the growth of a successful economy. According to the report, about one fourth of the 48.7 million graduates of the country have a background in science education. There are 39.2 million graduates in all (22.3% of whom are from the science stream), 9.3 million postgraduates (19.4% are from the science stream) and 0.3 million doctorates (one-third from the science stream).

The report is optimistic in its views about the attitudes of students toward science. Three quarters of teachers who participated in the National Science Survey conducted in (200) were of the view that interest in science education was steadily increasing. Students at the high school level expressed greater interest in science education compare to those from middle school level. Students expressed greater interest in pursuing engineering and medicine after their high school rather than graduate programs in pure science. Students from urban areas were more motivated to opt for science background at the college level rather than those from rural backgrounds. The National Science Survey of 2004 indicates that there no decline in the proportion of students who wish to study science, but there are areas of concern which needs attention and improvement. Motivation, inadequate or outdated equipment, large class size, lack of computers, inadequate physical infrastructure, and lack of good teachers were some of the reasons cited by students for disinterest in pursuing science education. Teachers attribute cost of science education, difficulty of subject matter, limited job opportunities and arduous competition at the school and college level as reasons for disinclination of students to pursue a science career. Despite several challenges, the country has been successful in producing a large pool of skilled workers in various areas of science and technology and has strongly rooted its position in the global competitive market.

Chapter III

Review Of Related Literature

Nature of Science in Science Education

The construct "nature of science" (NOS) has been promoted as an important goal for science teachers and students studying science for approximately 100 years. Nature of science may be described as interplay of disciplines explaining what science is and how the scientific enterprise works (Clough, 2000). The National Science Teachers Association (NSTA) has advocated that understanding of the NOS as a critical factor in promoting scientific literacy. According to Lederman (2007), while understanding the importance of NOS to science education and science educators, we must consider the five main arguments proposed by Driver, Leach, Miller and Scott (1996). Their arguments were such that understanding the NOS helps us make sense of science and manage technology in several processes of everyday life. It also helps in making informed decisions on socio-scientific issues and helps appreciate the value of science as a part of a culture. Understanding the NOS also helps the scientific community to develop norms that are of value to the society. It also facilitates the learning of science subject matter. According to McComas, Almazroa, and Clough (1998), a better understanding of scientists and the scientific community will enhance the understanding of the strengths and limitations of science, interest in science and science classes, and the learning of science content. This lack of understanding of what science is and how the scientific enterprise works potentially is harmful in societies where citizens have a voice in science funding decisions, evaluating policy matters and weighing scientific evidence in legal proceedings.

Students and teachers understanding of the NOS and its implications to the society has been of topmost priority of science education, science education research and several national reform documents (American Association of the Advancement of Science [AAS], 1990; National Research Council [NRC], 1996; National Science Teachers Association [NSTA], 1982; Central Association of Science and Mathematics Teachers, 1907.) The nature of science recommendations contained in eight international science education standards documents (McComas & Olson, 1998) shows significant overlap. The recommendations were proposed for K-12 science students and teachers and not for philosophers of science.

Though the importance of the NOS has been stressed sufficiently in both national and international science reform documents, there seems to be difficulty in incorporating the essential elements of NOS in science classroom instruction. The elements included in science curriculum documents are essentially viewpoints of philosophers, historians and sociologists of science. Elby and Hammer (2001) argued that the consensus on the list of NOS items was too broad and that "a sophisticated epistemology does not consist of blanket generalizations that apply to all knowledge in all disciplines and contexts; it incorporates contextual dependencies and judgments" (2001, p. 565).

According to Rudolf (2000), educators need to be aware that a single viewpoint does not exist for the NOS but a curriculum needs to be developed where students are aware of the practices that exist within and across scientific disciplines. Changing the focus from a universal conception of NOS to the particularities of scientific practice for the design of science curriculum would enable students regard the experience and understand the rich diversity of the scientific enterprise.

Educators need to begin to exploit the vast literature of the science studies

> community, not to develop some universalist picture of science, the value of which is questionable, but to begin to understand what the various practices of science look like in all their myriad forms, in order to provide some reasonably authentic context in which to situate the scientific knowledge claims of the curriculum (Rudolf, 2000, p. 409).

Rudolf (2003) further clarifies that the universal portrayal of science does not seem to have any real educational significance besides the function of gate keeping wherein certain elements in the curricula and others omitted. Including viewpoints from researchers, research practices, and real world communities in the curriculum design who help students understand science better in our everyday world.

Wong and Hodson (2009) emphasize the value of scholarship of practicing scientists. They believe that scientists who are involved in innovative research or "science-in-the-making" can play a valuable role in shaping the viewpoints of science educators about the practices of scientific community, nature of scientific work, objectives behind scientific work and the inter-relationship between scientific community and the society. Previous work by Glasson and Bentley (2000) where six research scientists presented their innovative research to school science teachers at a research conference reflected on their work from an epistemological perspective. The scientists tried to reflect on how their research work was connected to the essential goals of NOS and science – technology – society (STS) issues. Scientists from traditional content disciplines reflected a strong commitment toward empiricism whereas those from engineering disciplines stressed on problem solving. A more recent study of Samarapungavan, Westby and Bodner (2006) of analyzing the NOS beliefs of 90 participants ranging from high school students to graduate students and researchers reveals that nature of science in science education may underrepresent some important discipline specific aspects of science.

The study authors urge teachers to consult the views of scientists and amount of NOS goals reflected in their scientific practice and consider including them in curriculum construction. By including the descriptions of scientific practices provided by well-established scientists with appropriate modifications to suit the cognitive levels of students, this can both enhance and enrich the understanding of NOS. The authors invited 14 research scientists from different countries whose career spans anywhere between 10 - 47 years in a wide range of sociocultural settings. The authors were keen in identifying the extent by which the viewpoints held by them is similar or dissimilar to the views being promoted in science education literature and in school science textbooks.- Their study indicates that the participating scientists held the view that science is universal and though there may be issues related to research funding and differences in national priorities and culturally determined interests, the practicing scientists strongly believed that science is universal and not conducted differently in different socio-cultural settings. The practicing scientists also shared that collaboration across different disciplines and competition was a part of their daily practice. The authors were optimistic that their study with the help of practicing scientists helped in debunking the universally identified image of science as being fully rational, carefully articulated, and the myth that scientific investigations proceed in a systematic manner from observation to hypothesis to experimental testing and finally accepted knowledge.

As science programs and science reform documents continue to emphasize the value of understanding the nature of science, students and teachers continue to hold many misconceptions related to the nature of science. This can dampen student attitudes toward science and science classes and can influence student learning and even selection of further science classes (McComas, 2000; Tobias, 1990).

A common misunderstanding among students is that they frequently confuse science with technology and the myth that technology is applied science often is portrayed in science textbooks (Ryan & Aikenhead, 1992). According to Zimman (1984), the purpose of scientific enterprise is to generate new knowledge for its own sake while technology responds to human and social needs. This erroneous misunderstanding of the relationship between science and technology may have real societal consequences when funding decisions are to be made (McComas, 2000).

Another common myth is that all scientists follow a common series of steps or the scientific method. This has been prevalent since Karl Pearson (1937) has proposed it. The steps listed for the scientific method typically are, (a) state the problem; (b) gather background information; (c) form a hypothesis; (d) make observations; (e) test the hypothesis; and (f) draw conclusions. More recent science textbooks do not list the steps in doing scientific research, but teachers continue to teach the scientific method misconception (McComas, 2000). The idea of the scientific method is so compelling that students may feel disappointed when they discover that research scientists do not have a posted copy of the steps of the scientific method in their laboratories. Closer inspection reveals that scientists approach problem solving not by a rigid systematic procedure but rather by using imagination, prior knowledge, creativity and perseverance.

Students typically tend to associate science with experiments and all hands-on activities conducted in the science class are labeled as experiments. A majority of the experiments in the science classes include verification activities. Addressing these during classroom discussions and readings, these activities confirm principles, concepts and laws already in place. Typically, most science teachers present the major ideas in the classroom lecture and discussion and these ideas are expanded upon during laboratory work. The relationships between variables may be verified in the laboratory. Students acquire greater meaning when they gather data and analyze data to verify laws and principles under investigation. Verification activities aid students in organizing hard and abstract concepts in a meaningful manner. However, one of the major drawbacks of this approach is that students tend to develop the notion that science is procedural in nature and there is little or no room for creativity and imagination. In addition, students tend to form the impression that science is associated only with experiments. True experimentation is useful but not the only route to knowledge. Many scientists also use non-experimental routes to advance knowledge (McComas, 1996).

The words theory, law, hypothesis are often used in science classes but their accurate meanings are rarely conveyed to students. Ryan and Aikenhead (1992) administered a survey to about 2,000 grade 11 and 12 students. When questioned about hypotheses, theories and laws, a majority of the participating students (64%) expressed a simple hierarchical relationship in which hypotheses become theories and theories become laws depending on the amount of proof available. Scientific laws also seem to enjoy a higher status compared to scientific theories. The authors observed students were ignorant of the fact that many laws, such as Boyle’s Law, were known before any theories existed explaining them. The authors caution that the naïve understandings of the students of important scientific epistemology can threaten scientific literacy in the future. Students also hold a strong belief that hypotheses refer to an "educated guess" or a prediction. Laws and theories represent different forms of knowledge but one does not transform into another.

McComas explains:

> Laws are generalizations or universal relationships concerning the way that some aspect of the natural world behaves under specific conditions. Scientific theories predict and explain laws and provide conceptual frameworks for further research (2000, p. 14).

Hypotheses may mean a guess or well-informed speculation used to explain an observation, laws or a theory.

Similarly, students should be able to understand the differences between observation and inference. Observations are descriptive statements about natural phenomena that directly are related to the senses and which several observers can reach consensus about with relative ease. Inferences go beyond the senses and at a higher level a scientist can infer models or mechanisms explaining observations of complex phenomena (Lederman, 2007).

Holding the belief that scientific knowledge is absolute and resistant to change is another common misconception. Facts, theories and laws are conditional and subject to change. New evidence made possible through advances in theory and technology create the result of change. Tentativeness in scientific knowledge may be attributed to the fact that scientific knowledge is inferential, creative, and socially and culturally embedded (Lederman, 2007).

Nature of Science is often confused with scientific inquiry or scientific processes. Scientific processes involve collecting data, observing, inferring, collecting and analyzing data and drawing conclusions (AAAS, 1990, 1993; NRC, 1996). Nature of Science refers to the rich description of what science is, how science works, how scientists operate as a social group and how society directs and reacts to scientific endeavors (McComas, Clough & Almazroa, 1998). NOS may be best expressed in the context of scientific inquiry and scientific processes. Scientific inquiry will provide students with the platform upon which the goals of NOS may be achieved (Lederman, 2007).

The knowledge of science teachers about the nature of science is significant because they play a key role in forming the image of science held by the public. Even though the media such as the television and the World Wide Web significantly influence the image of science held by people, the participation of schools in this process cannot be fully eliminated. An expectation exists of students throughout the country to enroll in science courses in their junior and high school years. The State Board of Education in Texas approved the "4 x 4 Plan" in 2007 and under this new plan students require 4 credits each year in four core subjects (English, Mathematics, Social Studies and Science) and the total number of credits required for graduation was increased to 26. Science credits must be earned in biology, chemistry, physics and another lab-based science of the choice of the student such as engineering, anatomy and physiology of the human systems or earth and space science is required. The 4 x 4 Plan was proposed to better prepare students for success in colleges and universities. Under this plan, students will participate in a formal study of science all through their high school years. Thus, in all public schools in Texas and most secondary schools around the country students do devote a large amount of their time to the study of various branches of science. Under this context, it becomes essential to understand the knowledge and perceptions of teachers with regard to the nature of science and what effect will this have on teaching science to the younger generation.

Gallagher (1991) conducted an ethnographic study of 27 science teachers from five schools in two different districts in order to gain an understanding of the practice of science teaching in secondary schools and the forces that influence science teaching. The teachers placed a large emphasis on science as a body of knowledge and terminology was predominant in assessments such as homework, quizzes and tests. Laboratory work was less frequent and students did not participate in more than 10 laboratory exercises per year. The teachers devoted no time in the discussion of the nature of science, such as how the knowledge included in the curriculum was formulated or the processes by which scientists validated the knowledge. The stated purposes of teaching science, according to the teachers themselves, were for preparing students for life, understanding the natural world, preparation for further study, developing reasoning skills of the students and identification of talented students who will be future scientists. Despite these lofty reasons, the practices of classroom teachers portrayed a completely different picture.

Except for the initial phase of school year, the emphasis on the scientific method and the objective nature of science gradually was dropped and ignored for most part of the remaining school year. The knowledge of science by the science teachers themselves was limited severely in areas such as the history, philosophy and sociology of science. Hence, these ideas were not included in their everyday teaching. Textbooks used by the science teachers emphasize heavily on science as a body of knowledge and do not acknowledge attitudes, applications and processes of science. Science teachers who depend on textbooks as principal teaching aid fail to portray a broader perspective of science to the youth.

In an attempt to understand why teachers teach the way they do, Gallager (1991) points out the deficits in teacher education and training programs. College level science courses focus predominantly on covering a large body of discipline-specific knowledge while little emphasis is placed on how the knowledge was developed or its applicability in daily life. Even though students are engaged in laboratory work, they did not extend the ideas or the processes beyond the laboratory. To understand about the processes or the nature of science, they would have to enroll in courses such as history, philosophy or sociology of science. The limited knowledge and understanding of the processes of science limits the abilities of both prospective and practicing teachers to plan and implement lessons that helps students conceive an image of science that goes beyond the "body of knowledge." This results in an inaccurate and inappropriate public image of both science and scientists.

In a study conducted by Lin & Chen (2002) the benefits of teaching chemistry through history was documented. Sixty-three prospective chemistry teachers enrolled in four years of teacher preparation program participated in this study. Thirty-three students belonging to the senior class were a part of the experimental group and thirty students belonging to the junior class formed the control group. The senior students completed their college chemistry course requirement and enrolled in chemistry teaching methods courses and history of science class conducted by the authors. The juniors completed most of their science courses requirement and enrolled in course related to the development of science education. Questionnaires provided to both groups prior to the study related to the NOS. During the study, the experimental group was provided with various historical materials prepared by the authors. The materials emphasized how scientists developed their understanding of certain phenomena and presented original debates, discussions and experiments. For example, the materials described how scientists developed their understanding about atoms, molecules and atomic weight tables. Instructional approach involved group discussions, debates, teacher demonstrations, project assignments, project assignments and hands-on experiments that simulated the works of scientists. After the completion of the course, both the experimental and control groups completed the questionnaire related to the NOS a second time and some teachers of the experimental group participated in an interview. Quantitative analysis of the results revealed that the experimental group made significant progress in comparison to the control group in understanding the nature of science, theory-based nature of scientific observations, and the role and function of scientific theories. Analysis of the interview also points out that the pre-service teachers of the experimental group clearly indicated that changes in their understanding of the NOS was brought about by reading cases in the history of science and they used these historical cases to support their beliefs during the interview.

Abd-El-Khalick and Lederman (2000b) assessed the influence of history of science courses on NOS perceptions of college science students and pre-service teachers. The pre- and post-treatment analysis of the NOS views held by the participants reveals that there was not much change in the inadequate views of NOS held by the participants of this study. The authors point out that in order to enhance the NOS understanding through the history of science approach, an explicit approach would be more effective than an implicit approach. It is important to guide students in a definitive manner while interpreting historical narratives from an alternative perspective. One may argue that by using an explicit approach, NOS views are imposed upon students. However, the authors carefully counter argue that certain persistent misconceptions of the NOS already have been imposed on students and it is not possible that these will have been completely implicitly internalized viewpoints of science from their school and college experience. Although a teaching of these naïve ideas about NOS is more likely. The authors propose that the students should be presented with sufficient conceptions of the NOS aspects and the historical examples and narratives will strengthen their understanding of various aspects of scientific knowledge and practice. Challenging their misconceptions prior to enrollment in history of science classes may only serve in strengthening and helping pre-service teachers develop more adequate and enriched viewpoints of NOS. Collaborative efforts between science educators and historians will be fruitful in terms of enhancing and enriching NOS viewpoints and objectives.

Abd-El-Khalick (2005) assessed the impact of philosophy of science courses on the NOS views of pre-service teachers. Researcher analyzed the lesson plans of the participants and reflection papers to assess the impact of the philosophy of science on the viewpoints of the participants of the NOS. The author observed that compared to the participants enrolled in a regular science methods course, those who were enrolled in the philosophy of science class developed a deeper understanding of the NOS and planned explicit instructional activities to teach about the NOS. The author carefully points out that the philosophy of science was not a “regular” philosophy of science course but was designed specifically to address the needs of science educators and influence their views on NOS and explore the implications of these views for science teaching and learning. The course designed keeping in mind to address and develop a clearer understanding of the NOS that goes beyond the few hours of NOS-related instruction in a science methods course. The participants in this course previously were exposed to views on NOS in their methods class. Moreover, they were able to derive more lessons about NOS from their experiences with history and philosophy of science. The measure of study success occurred in terms of the ability of the participants to think about changes they wanted to bring about in their own teaching and being able to use specific and accurate examples from history and practice of science in their reflection papers and discourses about the NOS. Scharman, Smith, James & Jensen (2005) used a similar explicit and reflective approach to enhance the understanding of the nature of science concepts among pre-service secondary science teachers. Students reaction papers, transcribed verbal comments made during classroom discussions, other classroom activities and reflection essays indicate that an explicit approach was successful to teach the NOS.

Schwartz, Lederman, and Crawford (2004) studied changes in secondary pre-service teachers NOS conceptions. The participants of this study were 13 Master of Arts in Teaching (MAT) students. The authors were interested in studying how the research experience coupled with seminars, journal assignments, and explicit instructions will influence NOS understanding. Authors point out that empirical research points out that engaging in scientific inquiry or simply “doing science” is not sufficient to enhance the NOS views. A gap exists between scientific inquiry and the NOS. The authors feel strongly about creating awareness between these two ideas and bridging the gap between these two ideas. Guided discourses and writing reflections supplemented the research experience of the participants and were critical for NOS conceptual developments. The teachers were exposed to guided attention and reflection on NOS in the context of scientific research experience. Overall, the research experience coupled with discussions and reflections proved to be fruitful in bringing about changes in most of the NOS viewpoints of the participants.

Schwartz and Lederman (2002) examined the knowledge, intentions, and instructional practices of two beginning science teachers as they learned the essential ideas of the NOS during their pre-service teaching program and during their first year of full-time teaching. The results of the study indicate that the teacher with a more expansive science background had a well-formed notion of the NOS and was able to address it more efficiently and frequently in his classroom teaching. The limited subject matter of the knowledge of the other teacher and the compartmentalized views of NOS inhibited her recognizing when and how to teach NOS topics more frequently in the science classroom. The authors point out that strong subject-matter knowledge and a strong NOS knowledge are essential to improve the frequency of NOS inclusion in classroom science lessons. Though the teachers faced obstacles typical to first year teaching, such as classroom management issues and time-management, they held strong intentions and beliefs that NOS was an important topic to address in their teaching and consistently addressed it throughout their first-year teaching. This study is interesting in the aspect that it points out the extent by which subject-matter knowledge may affect NOS inclusion in the classroom teaching.

In a study conducted by Bell, Lederman, and Abd-El-Khalick (2000), the authors observed the teachers translation of NOS knowledge in the classroom. A measurement of the knowledge of the subjects, i.e. pre-service teachers, concerning NOS occurred both before and after student teaching. Throughout the student teaching term, the researchers to see if the teacher had included NOS in science teaching explicitly analyzed daily lesson plans, classroom videotapes, portfolios and supervisor's clinical observations notes. The authors observed that though the teachers had sufficient knowledge and acknowledged the need and importance of including NOS in science teaching, it did not translate into classroom teaching. The pre-service teachers faced conflicts between teaching the NOS and more commonly addressed topics of science content. They also faced challenges such as keeping up with their mentor teachers, lack of time, and lack of confidence in their understanding of the NOS. These factors constrained them from addressing the NOS in the classroom.

According to Lederman (2007), a few generalizations may be justified with respect to the teaching and learning of the NOS. These include the fact that both K-12 teachers and students do not possess an adequate understanding of the NOS. The viewpoints of the teachers on the NOS does not necessarily translate into classroom teaching due to a variety of factors such as lack of time, lack of confidence in understanding, academic background, and influence of teacher preparation program etc. Abd-El-Khalick and Lederman (2000a) point out that the teacher preparation programs and courses have certain limitations to the extent by which the views of the teachers regarding the NOS may be enhanced.

The Role of Textbooks in Communicating the Nature of Science

The role of textbooks in instructional planning and in the classroom has proved to be critical (Weiss, 1993). The United States has the distinction of ranking high in the frequency of textbook usage as a means of instruction in the classroom (Lapointe, Mead, and Phillips, 1989). Stake and Easley (1978) point out that the source of knowledge authority in the classroom was the textbook and not so much the teacher. The textbook carried the instructional burden in the science classroom and seems to be doing the job most teachers, students, administrators, and parents expected of it. They write:

> Over 90% of science teachers …said their instructional materials were the heart of their teaching curriculum 90-95% of the time. Behind nearly every teacher-learner transaction….lay an instructional product waiting to play its dual role as medium and message. They commanded the attention of the teacher and the learner. In a way, they virtually dictated the curriculum. The curriculum did not venture beyond the boundaries set by the instructional materials (Stake & Easley, 1978, p. 66).

Though the teachers explained and described the essential points, the direct confrontation of knowledge of the students was with the textbook. Every class made use of printed instructional material either in the form of textbooks or lab manuals, encyclopedias, maps, and charts. The authors also point out though the teachers explained and at times shared their personal experiences; the attention of students mostly was directed to the information contained in the textbook readings. Often, students are directed to search the text for the sentence which contains the correct answer rather than understanding and reasoning the ideas. The authors have a strong impression that many schools chose the popular texts and workbooks for classroom instruction.

The National Survey of Science and Mathematics Education (2000) reports that 8% or more of grades 5-8 and 9-12 science classes were dependent on textbooks and covered substantial portion (75% or more) of the textbooks. Science classes were more likely to use multiple textbooks and programs as compared to the other disciplines. However, the dependence of a single textbook was more prevalent in science instruction between grades 9-12.

According to the survey (Addison-Wesley Longman, Inc/Scott Foresman; Silver, Burdettt and Ginn; and McGraw-Hill/Merrill Co.) account for almost 70% of textbook usage in grades K-4 science classes. Publishers (Prentice Hall; McGraw-Hill/Merrill; and Addison-Wesley Longman, Inc./Scott Foresman) account for 64%% textbook usage in grades 5-8. Publishers (McGraw-Hill/Merrill Co; Holt, Rinehart, Winston; and Prentice Hall) account for 69% of grades 9-12 textbook usage.

The report points out an interesting fact that most teachers considered the textbooks to be relatively of high quality (56-78%) as opposed to the critical view of quality of textbooks held by national experts in science education.

The importance of textbooks in science education has been emphasized in science reform movements. AAAS through Project 2061 produced case studies, which analyzed science textbooks for their alignment with the Benchmarks for Science Literacy. Project 2061 has evaluated the credence of science curriculum material through valid and reliable procedures. These procedures have been developed from the invaluable input of numerous K-12 teachers, teacher educators, materials developers, scientists, and cognitive researchers. The main objective of the evaluation tool was to judge whether the curriculum materials fulfilled the attainment of important benchmarks and standards.

Student textbooks and teaching guides were evaluated using several criteria components such as whether key ideas were built on prior knowledge and if students were allowed to interpret their learning experiences and if there were evidences of extending key ideas to the natural world (Kesidou & Roseman, 2002; Stern & Roseman, 2004). Project 2061 has produced a database of analytical reports of middle-school science curriculum materials and these reports are available on the website of Project 2061 at: www.project2061.org

For example, the study conducted by Kesidou & Roseman (2002) examined middle-school curriculum materials (student and teacher versions of the textbook) to see how well they supported key scientific ideas specified in national documents, namely the *Benchmarks for Scientific Literacy* (AAAS, 1993) and the *National Science Education Standards* [NSES] (NRC, 1996). The reviewers who participated in this study were experienced middle school classroom teachers and science education university faculty. The study confirmed that many of the topics covered were at a superficial level and very few topics were treated in depth. There was heavy focus on vocabulary and technical terms with little attention toward the cognitive thinking and prior knowledge of the students. The key ideas were buried between conceptually difficult or unrelated ideas making it difficult for students to focus on the main idea. The curriculum materials failed to connect the integral ideas to real-world phenomena and failed to help students overcome their misconceptions. The teacher guides seemed to provide minimal help in terms of suggested activities that could help students overcome their difficulties. It did not provide explicit knowledge of the problematic ideas which students are likely to face, hence it is unlikely that teachers may deal with these ideas in the class.

The authors observed that the National Science Foundation (NSF) funded materials that reduced the amount of content to be covered, limited the use of vocabulary terms, and provided opportunities to students to explain their own ideas. However, the limitations of these materials included the lack of logical explanations of real-world phenomena using key ideas, the prior knowledge and beliefs of the students were not taken into account. Moreover, these provided limited opportunities for teachers to help students understand the key ideas.

A similar study conducted by Stern & Roseman (2004) evaluated the concept of matter cycles and energy flow in life-science curriculum materials. The ideas of how matter cycles and energy flows from one living thing to another and between organisms and the surrounding environment. These key concepts connect several other ideas such as the food chain to more complex ideas like photosynthesis and respiration.

The findings of this study are very similar to the previous one. The content of the analyzed materials did not contribute to the attainment of benchmarks and standards as prescribed in the national documents. A large amount of text material was allocated to topics related to the flow of matter and energy (no other topic in life science received more attention than the flow of matter and energy), but the key ideas were dispersed between unrelated materials making it difficult for students to focus on the main ideas. Ideas pertaining to matter and energy merely were repeated over and again in the text. However, they were not extended to new contexts or revisited in progressively higher levels of sophistication.

The textbooks did not succeed in tying together different relevant experiences that students had with key ideas nor did it challenge the naïve conceptions held by the students. The hands-on and inquiry-derived activities were not particularly relevant to the key life science ideas nor did they explicitly link them. The experiments involved complex set-ups, required students to draw conclusions based on insufficient evidence and there was greater focus on experimental skills rather than the ideas. The authors emphasize the need for valuable curriculum materials, which improve both teaching and learning processes. According to them,

While better curriculum materials alone are unlikely to improve student learning, we think that high-quality curriculum materials can positively influence student learning directly and through their influence on teachers. For these reasons, valid identification of curriculum materials that actually support teachers build their own content and pedagogical knowledge is essential. (Stern & Roseman, 2004, p. 539)

Munby (1976) postulated that language used in science instruction, particularly in science textbooks, might influence the perception of the students regarding the nature of science. Cautioned about misunderstandings that may easily arise from the ways in which science is communicated, science educators are urged to pay attention to the importance of language used in communicating science to the outside world. Language shift arises when familiar phrases take on new meanings in science. If the reader is not aware of the contextual change, then the phrases will be interpreted within the context of ordinary language rather than the scientific language. This may lead to the misinterpretation of the nature of science and the scientific knowledge.

Different ways of communication may result in different understandings about science. The language used in science instruction may be either instrumentalist or realist. According to the instrumentalist view, theoretical or explanatory statements in science are neither true nor false statements but simply ways of making inferences about phenomena, ways of conceptualizing and explaining scientific data. This way of communicating science indicates that science is very subjective. On the contrary, the use of a realist language depicts a completely different picture. It portrays scientific theories and explanations as true descriptions of the real world where scientific objects have a physical existence. Realist language use in texts depicts science as a matter of reality whereas an instrumentalist language usage depicts the notion that science is a matter of explaining what is perceived. Students may have different understandings of the nature of scientific enterprise from these two ways of communication in science textbooks.

Chemistry is a content packed subject and the majority of instructors derive their course material directly from textbooks. Instructors who have heavy teaching loads are usually unable to generate their own examples for teaching from primary source materials and are compelled to rely on textbooks for both subject content and pedagogical approach.

Smith and Jacobs (2003) conducted a study to analyze the time spent using various textbook resources by both students and instructors. Their study involved a total of 3,200 first-year general chemistry and second year organic chemistry students and 23 instructors at nine U.S. institutions. Additionally, 10 chemistry books were analyzed. Students and instructors answered questions relating to the time spent using various textbook resources, and the quality and helpfulness of the books at the end of the first semester of taking the course by answering questions to a survey prepared by the authors using the TextRev website.

The study revealed that general chemistry students reported that they spent an average of 4.1 +/- 0.1 hours per week using resources such as textbooks, study guide, solutions manual, the textbook Web site, and accompanying electronic resources such as the CD. The organic chemistry students spent 5.8 +/- 0.2 hours per week using the textbook and related resources. For general chemistry students, the data revealed a significant correlation between the number of hours spent using the textbook resources and the anticipated letter grade by the student (ANOVA: $F = 10.9$, $p = 10^{-7}$). Through observations, students who secured a lower letter grade spent more time using the textbook. In the case of organic chemistry course, there was no significant correlation observed between the letter grade and the number of hours spent using the textbook and the anticipated letter grade of the student (ANOVA: $F = 0.62$, $p = 0.60$). Typically, students with high school chemistry background usually do not spend much time preparing for general chemistry courses unlike organic chemistry, where the material is new for a larger fraction of the class and student time commitment tends to increase. Hence, there is no significant correlation between student letter grade and the time spent studying the course for organic chemistry.

General chemistry students spent an average of 64 +/- 3 % of their time using the textbook and 29 +/- 2 % of their time using the study guide and solutions manual. Organic chemistry students spent a smaller fraction of their time (58 +/- 5 %) using the textbook and more time (36 +/- 2 %) using their study guide or solutions manual. The organic chemistry students rated the solutions manual and study guide more beneficial as compared to the general chemistry students. Both groups did not dedicate much time (only around 7 +/- 1 %) to the electronic resources such as the textbook companion website and accompanying CD.

The authors point out that if exams and graded assignments did not require students to solve questions based on animations, simulations, or other electronically delivered materials, then most students did not spend the time to work with these resources. In order for these resources to be utilized more frequently, it is necessary for instructors to draw matter explicitly from these electronic resources and integrate it with homework, end-of-chapter problems, quizzes and other assessments.

General chemistry students rated the real world applications from textbooks as more useful compared to organic chemistry students. Organic chemistry students rated images and photographs from textbooks as more helpful in understanding the content. This study provides a snapshot of how chemistry students used and valued their textbooks and related textbook resources and reveals some information related to study habits of first and second year college chemistry students.

Stucke and Gannaway (1996) point out that content analysis of textbooks will be useful in determining what to teach. Other options include looking at standardized tests to determine the objectives to teach, consulting expert panels to identify what is recommended and referring to documents such as Benchmarks for Scientific Literacy and National Science Education Standards. These documents clearly identify benchmarks which students are expected to know by the end of the school year. In order for chemistry textbooks to facilitate learning, chemists and chemical educators need to develop cluster goals about what chemical education needs to accomplish. These goals need to include the following ideas such as:

1. Students should understand the nature of the scientific enterprise;

2. Students should be familiar with career opportunities available from chemical education; and

3. Students need to make connections between the macroscopic world of observations and microscopic world of atoms and molecules. If students do not make this connection, they will fail to see the importance and relevance of chemistry to the world and its centrality with respect to the other branches of science (Gabel, 1983; Gillespie, 1997).

Project Synthesis outlines four area goals related to societal issues, career education, salient knowledge and personal needs. When chemistry texts were surveyed, rarely these four goals are reflected in a single program or book (Gabel, 1983). Claiming to be well written, Chemistry texts often include many beautiful illustrations, yet continue to present the material in the same traditional manner. Gillespie explains:

> No matter how excellent these texts appear to the instructors who choose them, they have not succeeded in interesting the vast majority of students or in providing them with an understanding of chemistry – or even with useful information that they remember and use later in life (1997, p. 484).

One of the fundamental issues in chemistry instruction is the obsession of large amounts of content. Textbooks and instruction are focused more toward delivery of content rather than the building of cognitive skills. Owing to the large size of textbooks, typically more than one-thousand pages long, teachers feel compelled to include more content in their classroom teaching. Standardized tests strongly influence the amount of content covered in the classes. High school chemistry textbooks have begun to resemble college texts in the number of pages and content. In order to include recent advances, chemistry textbooks are more than thousands pages. A heavy content laden textbook can easily depress young students who may lack the ability to distinguish between trivial from important information (Cohen, 1986).

Kerber (1988) owes the elephantiasis of the textbooks to the problem of not deleting the no-longer-so important older material than the addition of exciting new material. The content, organization, and development of chemistry texts greatly are influenced by market research (Herron, 1983). Such research provides information regarding details of texts in use, topics covered, and the type of students enrolled in chemistry courses. The nature of research is such that it guarantees that curriculum materials will not change, even if change may lead to greater learning experience. Publishers are private corporations whose major concern is to produce the maximum return on the capital invested. Publishers prefer to produce books that meet the needs of a diverse population. Teachers chose the books for their classes whereas students simply use them. Even though a book may appear to be good for an instructor, it may be quite ineffective to the student. Market research aims at making books attractive to the teacher. Most teachers and textbook authors view learning as a process of absorbing vast amount of information.

Learning is a constructive process and is influenced by prior knowledge at the time new information is constructed. When a chemistry teacher reads the textbook, he or she accesses the prior knowledge to make sense of what is presented in the textbook. However, this may not be necessarily true for students. Students lack the prior relevant knowledge and many lack the reading ability and vocabulary to understand the passage. Accessing information through verbal cues may not be the only way to provide meaningful context for new information. Illustrations, diagrams and experiments are also helpful. New concepts are developed through a process of successive refinement, yet can be misled if textbooks provide inappropriate or insufficient examples for student learning to take place.

Authors and teachers need to be sensitive to the needs of the students and textbooks need to be written so that students understand them and knowledge is constructed in a meaningful manner. Research in education does not seem to have any effect in the quality of textbooks. It is not possible for teachers to keep abreast of the new developments in education research due to their classroom commitments. However, publishers can keep up with latest educational practices and provide textbooks, which are both pedagogically sound and effective.

New technologies and advancement in science have resulted in tremendous increase of vocabulary in science textbooks. Rowe (1993) critiques science textbooks have an average of 7-10 new concepts, terms, or symbols per page. In a school year of 180 days, and class periods of approximately 55 minutes each, 20 concepts have to be covered per period at an average of one concept every two minutes. This will simply lead to frustration of both teachers and students. Selvarathnam (1993) points out students memorize many items of knowledge that are unnecessary. Hence, it is important for teachers to recognize what needs to be included in the curriculum.

Most students deal with college chemistry topics on a recall or rote basis (Gabel, 1983; Gold, 1988). Often colleges dictate what needs to be taught at the high school level thereby compelling teachers to cover voluminous amount of content. Chapters in textbooks have become more theoretical and mathematical in nature. Concepts such as quantum numbers, orbital shapes, and nomenclature should not be memorized.

The knowledge of teachers in chemistry will be helpful in selection of core material that will contribute to the cognitive development of the student while discussing some of the many topics found in texts. Textbooks demonstrate problem solving using sample problems based on algorithms rather than reasoning. Students tend to memorize the process rather than reasoning out the solution. Complex mathematical processes such as logarithms used to solve pH problems can easily confuse students. Complex diagrams such as titration curves are not very helpful in learning. Topics such as moles and redox reactions usually are presented with no basis in experimentation.

Gold (1988) makes an earnest plea to teachers that they need to attempt to create a better balance between teaching of content and development of cognitive skills. Pauling (1983) emphasizes the fact that the information presented is far more than what students could be expected to learn in one year and is presented at an advanced yet superficial level that it will only turn students away than actually attracting them to the field. Concepts such as molecular orbital theory will only confuse students and the discussion of molecular structure may be limited to simply valence bonds.

Chemistry of textbooks and everyday classroom bears very little similarity to the chemistry of a research laboratory. Every textbook presents its own scientific method and there are as many scientific methods as there are scientists (Fernandez & Worrell, 1991). Scientific research involves creativity besides factual knowledge. A scientist is engrossed in his work whereas a non-science major often emerges from a course in chemistry with the notion that the subject is dry and boring. Fernandez & Worrell (1991) argue that both non-science majors and science majors should be exposed to the same chemistry – principles, drill necessary to understand them, and the appreciation of the real nature of chemistry as a scintillating and evolving science rather than mundane textbook problem solving. In the words of the philosopher, Miguel de Unamuno (1972), “Chemistry ought not to be for chemists alone.”

Several studies have focused on the representation of NOS themes or aspects in secondary school textbooks and chemistry textbooks in particular. Brito, Rodriguez and Niaz (2005) evaluated 57 freshman college-level general chemistry textbooks with respect to the presentation of the periodic table using a history and philosophy of science (HPS) framework. Evaluation of the textbooks based on seven criteria developed using the HPS framework shows that almost all textbooks discussed the accommodation of elements according to their physical and chemical properties.

Very few textbooks neither outlined the possible causes for periodicity in the periodic table using the historical development of the periodic table nor explained periodicity as a function of atomic theory. Textbooks present a finished product of the periodic table ignoring that scientists for almost a 100 years (1820-1920) were trying to explain the underlying pattern for periodicity. The textbook approach does not facilitate an understanding of the student with respect to the tentative nature of science. Furthermore, Mendeleev’s arrangement of the elements in the periodic table was not limited to empirical evidence. Most books ignore the fact that scientists were looking for a theoretical basis of the periodic table, including Mendeleev. With theories considered as a work-in-progress, in the future a better explanation might be the electronic theory.

Textbooks fail to include the tentativeness of theories, another important facet of the nature of science. Very few books attempted to weave the development of the periodic table as a sequence of heuristic principles.

Atomic theory is a component of every science class taken by the student. The Bohr model, a more elementary way of looking at the atom is repeated in both middle school and secondary-level textbooks. The quantum mechanical or the wave-model is a more sophisticated model describing electrons based on their wave and particle property. The transition from the Bohr model to the quantum mechanical model of the atom is usually abrupt providing students with very little conceptual change.

Shiland (1995, 1997) analyzed eight secondary chemistry textbooks whether quantum mechanics have been accepted over the simplistic Bohr model based on a conceptual change model. The conceptual model used to analyze the textbooks was based on four factors: (1) dissatisfaction – learners are exposed to phenomena that their current conceptions are unable to explain; (2) intelligibility – learners must be capable of making an internal representation of the new conception; (3) plausibility – the new conception should be able to solve the problems the old conception failed; and (4) fruitfulness – the new conception should lead to the possibility of additional applications (Postner, Strike, Hewson & Gertzog, 1982).

Analysis of the secondary chemistry texts revealed that the dissatisfaction of the Bohr model was explained in one to two sentences and did not include any text to the pictures of spectra that could not be explained by the model. Brief explanation of the limitations of the model is not sufficient to create adequate dissatisfaction of the Bohr model. Learning theory calls for students to construct new knowledge and link it to prior knowledge but having a one-sentence transition to more than ten-pages of abstraction is logically insufficient. Each textbook devoted several pages ranging from five to 18 pages toward the discussion of the quantum mechanical model, in contrast to other theories like the Dalton theory, or the kinetic theory.

The abstract content of these pages included shapes of orbitals, sublevels, quantum numbers etc. Additional examples to illustrate the advantages of the model were not mentioned in any of the books. Problems related to the application of the quantum mechanical model were scattered throughout the textbook but required students to recall abstract features of the quantum mechanical model. The author concludes that the secondary chemistry textbooks did not provide a sufficient rationale to justify the quantum mechanical model over the Bohr model. Teaching students to understand scientific theories may lead to changes in the epistemology of a student toward a more rational world (Strike & Posner, 1992) and may also provide students the opportunity to accept that scientific theories are subject to changes and modifications and are not unchangeable and will lead them away from the inaccurate final-form view of science (Duschl, 1990).

Promoting student understanding and awareness of various issues and problems related to science-and-technology is essential so that they may take the responsibility for finding suitable action, and make informed decisions or choices in their everyday life that may ultimately lead to the solutions to these problems. Science-Technology-Society (STS) identified by the National Science Teachers Association (NSTA), Departments of Education in a variety of states, and by many commissions and panels with reform in science education as a new goal in science education.

Chiang-Soong and Yager (1993) analyzed 11 textbooks at the secondary school level (of which two were Chemistry textbooks) to see how much of the narrative material is devoted to the treatment of the STS material and how textbooks varied across grades with respect to the focus given toward STS material. The criteria for analyzing the STS material in the textbooks were adapted from Project Synthesis and Piel's report (1981). Piel's classification of STS topics included the following constructs – energy, population, human engineering, environmental quality and utilization of natural resources, space research and national defense, sociology of science and effects of technological developments.

Analysis of the textbooks revealed that less than 7% of the narrative space was devoted to STS topics, with a range of 11.5% to 0.5%. The amount of STS material in the two chemistry textbooks ranged from 0.6% to 2.3% and the material related to human engineering, space research, national defense, and sociology of science was very limited. The authors also observed that STS material decreases as the grade level increases. A great discrepancy exists between goals for science education, particularly in the emphasis of STS material and actual coverage of STS material in commonly used science textbooks. The authors urge textbook authors and publishers to be aware of this deficit and make amends by including more STS related material to the narrative of science textbooks at all secondary grade levels. In the words of Alan Voelker (1981):

> We want a science program that is truly responsive and responsible to the citizen in a scientifically and technologically oriented society, we must elevate current and future citizen concerns. We cannot assume that curricula, which emphasize traditional cognitive knowledge and an understanding of the scientific process,

> will lead to an understanding of the science-related issues confronting society. Neither can we assume that such traditional curricula will assist our student-citizens in applying their scientific knowledge and processes to these issues. Some sacred cows of the science curriculum must be eliminated. Nevertheless, the short-term trauma this sacrifice may elicit will be replaced by long-term gains for all citizens (p. 79)

Kahveci (2010) explored Turkish chemistry and science textbooks as indicators of reform in areas of gender equity, questioning level, science vocabulary load, and readability level. Forty pre-service teachers were guided to analyze 10 middle school science textbooks and 10 high school science textbooks.

Illustrations and text references were used as indicators for gender equity in order to find out whether females and males equally were represented in both levels of textbooks. Analysis revealed that overall both middle and high school science textbooks exhibited unfair gender representations. The male representations dominated both sets of textbooks as compared to the female representations and high school books were twice as much gender unbalanced in comparison to the middle school books. The only female scientist appearing in the textbooks was Marie Curie, mentioned with her husband, Pierre Curie, but several male scientists were referenced in both levels of textbooks. The underrepresentation of women in science, engineering and mathematics, has been of concern to science education reform and practice. Gender inequality representations in textbooks may only serve to discourage girls and foster negative attitudes toward science.

The textbooks also were analyzed in terms of frequencies of input, processing and output questions. Input questions require recall of information, processing questions require students to identify relationships among information, and output questions require students to apply and extend the ideas learnt to solve new problems and situations in the real world. Processing questions (73.9% of all questions) and input questions (43.5% of all questions) dominated high school and middle school textbooks respectively. The low proportion of output level questions (12.5% for high school books and 22.0% for middle school books) was noticeable in both sets of books. The author observes that a truly inquiry-centered textbook would include a large number of output questions in comparison to input and processing questions. Interesting output questions may lead students to be active learners by allowing them to collect, organize and analyze data. The author points out that the reason for a high frequency of input and processing questions in textbooks may be due intentional efforts of curriculum designers and textbook authors to prepare the middle school and high school students for highly competitive centralized national examinations enabling them to seek admission in prestigious high schools and university programs.

The study also revealed that high school chemistry textbooks placed a higher emphasis on science vocabulary with an average of nine vocabulary terms per page as compared to middle school textbooks. Such a heavy emphasis on science vocabulary terms only tends to make students consider science as a body of knowledge, needing memorization. The readability of the middle school and high school texts were found to be 54.5% and 47.6% for high school and middle school texts respectively. The reason for average reading comprehension was attributed to the heavy emphasis on scientific terminology. The author also points out that memorization scientific terms or body of knowledge is a hindrance to teaching science as inquiry.

A few studies have examined science textbooks from the NOS perspective. Chiappetta, Fillman and Sethman (1991a, 1991b) conducted a series of textbook analyses, developed a procedure, and established reliability for analyzing middle and high school science textbooks. The authors used four dimensions to determine the extent to which the nature of science is represented in science textbooks. The four main themes include science as a body of knowledge, science as a way of investigating, science as a way of thinking and the interaction of science with both technology and society.

Science as a body of knowledge is a result of many scientific endeavors that have occurred over several centuries. The body of knowledge consists of facts, concepts principles, theories and laws each having their own specific meaning. Science as way of thinking refers to how science, or scientists in particular, went out "finding about science." This theme tells students how scientists use a variety of approaches such as deductive reasoning, cause-and-effect relationships to advance their understanding. Sometimes scientists have to indulge in skepticism before they accept any scientific claims but also need to be objective and open-minded. The investigative nature of science promotes the "doing" aspect of science and is supported by text related to experiments, observations, data collection and analysis. Interaction of science with both technology and society deals with the applications of science (Chiappetta & Kolballa, 2002).

Chiappetta, Sethna and Fillman (1991) analyzed seven chemistry textbooks using the tenets of scientific literacy. "Chemistry in the Community (ChemComm), a publication of the American Chemical Society (2006), had most balanced treatment of the four themes of scientific literacy among the seven textbooks analyzed. The book devotes

26%, 43%, 1% and 30% to science as a body of knowledge, science as a body of investigation, science as a way of thinking and the interaction of science with society and technology respectively. All textbooks deemphasized science as a way of thinking. The authors emphasize the fact that it lies in the hands of the instructor carefully to select chapters, sections within chapters, questions and problems that would help students develop an appreciation for chemistry and science.

The authors address the fact that it is crucial for teachers to emphasize the importance of understanding the principles rather than simply focus on covering voluminous amount of content. The study of Lumpe and Beck (1996) showed that the four themes of scientific literacy were not represented effectively and violated the holistic nature of science. The science content of the analyzed textbooks was disconnected from the nature of science approach used by scientists to develop theories and ideas.

Abd-El-Khalick, Waters and Le (2008) assessed the representation of NOS in high school chemistry textbooks over the past four decades. The focus of the study was to identify the extent by which NOS representations have changed during the past four decades and the extent to which these changes reflect knowledge and understanding of the NOS. Analysis focused on the empirical, tentative, inferential, creative, theory-driven, and the social aspect of the NOS. The myth of the "scientific method," misinterpretation of scientific laws and theories, and social and cultural aspect of science were some of the other tenets of the NOS included in the analysis.

A total of 14 textbooks, including five "series" spanning from one to four decades, were analyzed. In general, the authors point out that the analyzed textbooks did not represent the target themes of NOS adequately in consistent with prior research findings (Chiappettta et al., 1991; Lumpe & Becke, 1996). Figures and charts contributed to a lesser extent in conveying the tenets of NOS as compared to textual statements. None of the analyzed textbooks represented all the targets of NOS effectively.

The social aspects of science were addressed in the form of implicit references to collaborative nature of scientific research, peer review process and constant communication between scientists. The "scientific method" continually was portrayed as a systematic, universal procedure in high school chemistry textbooks. The textbooks, however, fared a better job in addressing the inferential and empirical aspect of NOS in comparison to the creative and tentative aspect of NOS.

Majority of the textbooks clarified the nature of scientific theories whereas half of the textbooks either failed to address or inadequately addressed the nature of laws. The study reveals that the textbooks published in the late 1960s scored much better compared to those in the 1990s. This is quite disconcerting considering the fact that there was great emphasis for the NOS in science education during that period (AAAS, 1990; NRC, 1996). The textbooks not only failed to increase their attention to NOS but also continued to misrepresent certain facets of NOS.

Textbook publishers are discredited for the misrepresentation or inadequate representation of NOS (publisher effects) in school and college science textbooks. However, this particular study proposes an "author effect" instead, where textbook authors seem to hold on to their beliefs and views about the NOS (even if incorrect) for several decades and seem to be disserved from both national and international reform documents in science education, advances in the philosophical, historical, and sociological aspects of the NOS. This study clearly points out that NOS failed to serve as a central unifying theme in science textbooks. A few ideas regarding the NOS were dispersed throughout the analyzed materials but they were naïve and were inconsistent with the current viewpoints of the NOS.

Chapter IV

Research Methodology

Over the years, science textbooks in the United States have become larger and heavier, immersed with colorful photographs, diagrams, flowcharts, mini-lessons, activities, and sidebars. However, findings from the literature indicate that despite the enhanced quality and appearance of textbooks, they fail to teach science well. Nelson, former astronaut who directs Project 2061, criticizes science textbooks and remarks "students are lugging home heavy texts full of disconnected facts that neither educate nor motivate them" (Budiansky, 2001, p. 24). Science is not a mere body of knowledge or a set of terms or facts that need to be memorized by students. Textbooks or any other instructional material used in the classroom need to portray how science actually works and how the natural world may be understood using evidence.

The focus of this study was the extent to which science and the scientific enterprise were portrayed in high school chemistry textbooks from India and the United States. Chemistry, a major scientific field, is referred to as the central science (Corwin, 2011) due to its relevance to daily life, versatile application, career opportunities and innumerable benefits to society. Knowledge of chemistry is useful in areas such as improvement of health care, conservation of natural resources, protection and care of the environment, and provision of everyday needs such as food, clothing, and shelter (Brown, LeMay & Bursten, 2006).

Research Method

Content analysis is a valuable research technique used to study behavior exhibited in different forms of communication. Some of the definitions attributed to content analysis in the literature are as follows:

Content analysis is a research technique for making replicable and valid inferences from data to their context (Krippendorf, 1980, p. 20). Quantitative content analysis is the systematic and replicable examination of symbols of communication, which have been assigned numeric values according to valid measurement rules, and the analysis of relationships involving those values using statistical methods, in order to describe the communication, draw inferences about its meaning, or to infer from the communication to its context, both of production and consumption (Riffe, Lacy & Fico, 1998, p. 25).

Content analysis is the summarizing of quantitative analysis messages that relies on scientific methodology (including attention to objectivity, inter-subjectivity, a priori design, reliability, validity, generalizability, replicability and hypothesis testing) and is not limited as to the types of variables that may be measured or the context in which the messages are created or presented (Neuendorf, 2002, p. 10)

Content analysis is not restricted to only textbooks but may also include analysis of other forms of communication. Some of the common subjects of content analysis include textbooks, newspaper articles, transcribed speech, and visual images. The basic assumption of content analysis is that texts are concerned with social reality and results of analysis and their interpretations are dependent (Bos & Tarnai, 1999).

The content analysis methodological approach has been used to analyze several science textbooks (Wang, 1998). Chemistry textbooks have been analyzed for gender equity (Bazler & Simons, 1991), science, technology and society topics (Chiang-Soong & Yager, 1993), scientific literacy (Chiappetta, Fillman & Sethna, 1991a), gas properties (deBerg & Treagust, 1993), mole concept (Straver & Lump, 1993) and nature of science (Abd-El-Khalick, Waters, & Le, 2008).

Research Questions

The research questions proposed in this study include the following:

1. What is the balance of five aspects of nature of science (knowledge, thinking, investigation, interaction of science with society, interaction between science, engineering, and technology with society) in high school chemistry textbooks that are used in the United States?;

2. What is the balance of five aspects of nature of science (knowledge, thinking, investigation, interaction of science with society, and interaction between science, engineering, and technology with society) in high school chemistry textbook that are used in India?; and

3. What are the similarities and differences in the representation of nature of science in chemistry textbooks used in the United States and India?

The four themes or categories of the nature of science namely science as a body of knowledge, as a way of investigation, thinking, and interactions between science and society is based on previous studies of the textbook analyses and the nature of science developed by Collette and Chiappetta (1984) and employed by several other researchers such as Brooks (2008), Lee (2007), Phillips (2006), Chiappetta, Sethna, and Fillman (1991, 1993, 2004) and Garcia (1985) who reported reliable and meaningful findings with respect to the themes of nature of science. This proposal includes an additional fifth theme to the nature of science and this includes the interaction between science, engineering, and technology. The fifth theme was proposed based on the new *Framework for K-12 Science Education* (NRC, 2012) produced by the National Research

Council that strongly advocates engineering and technology education in science classes from K-12.

Science as a body of knowledge represents knowledge from many scientific fields as a result of creative products of human invention that have occurred over several centuries. The body of knowledge includes facts, concepts, principles, theories, and laws and each have their own specific meaning and often misinterpreted in science textbooks. There is no standardized or universally accepted definition for facts, concepts, principles, theories, laws, and hypotheses and often they are poorly defined and used interchangeably. It is essential for the science teacher to point out the differences and supplement textbook information in the classes. According to the position statement on the nature of science by the National Science Teachers Association (1982), laws are generalizations or universal relationships related to how some aspect of the natural world behaves under certain conditions. Theories are proposed explanations of some aspect of the natural world and help explain phenomena. However, not all laws need have supporting theories and theories do not transform into laws with additional evidence. Further, it is important to understand that well-established theories and laws need to be internally consistent and applicable over a wide-range of phenomenon to which they pertain. Scientific knowledge is both reliable and tentative, and maybe abandoned or modified in light of new evidence.

Science as a way of investigation includes many processes that are used to construct knowledge such as gathering information from many sources, making observations, conducting experiments, engaging in hands-on activities, and using charts and constructing models. However, school science often portrays science as a rigid systematic process called the “scientific method.” Scientific method portrays a naive notion as to how all scientists conduct their work and there is no one simple method of doing science. Some approaches used by scientists include making observations and inferences as in astronomy and ecology. Not all scientists are experimenters. Many are theorizers who explain data and pose questions guiding further inquiry. Textbooks typically portray science as an individualistic activity. However, collaboration and communication of scientific results to the rest of the world is an integral component of scientific research. Scientists communicate their results through peer-reviewed scientific journals in their field of study.

Science as a way of thinking involves beliefs and viewpoints held by scientists about the natural world. A great deal of scientific and technological knowledge is based on models constructed by scientists and engineers. Scientists may choose to use deductive or inductive thinking in reasoning their findings. Scientists need to be open-minded to new thoughts but may need to exercise skepticism before accepting any scientific claim.

Science drives technology and vice versa, and both are dependant and is dependent on society. Society, through government organizations such as the National Science Foundation and National Institutes of Health provides funding to research work in medicine, health science, agriculture, natural sciences, physical sciences and engineering.

The terms "science," "engineering" and "technology" are viewed often as a single entity. However, the *Framework for K-12 Science Education* (National Research Council, 2012) emphasizes the differences in meanings of these terms and the importance of integrating engineering in K-12 education. The fifth theme, will explore the interactions between Science, Engineering, Technology and its applications to society.

In the K-12 context, science is often restricted to the traditional natural sciences: physics, chemistry, and biology. Earth science, environmental science, aquatic science have been included in the curriculum in recent times. The new framework includes engineering and technology in K-12 science education as both fields strengthen the applications of science. The framework describes technology as “modification of the natural world made to fulfill human needs or desires" (NRC, 2012, p. 202). Engineering is described as "the systematic and often iterative approach to designing objects, processes, and systems to meet human needs and wants" (NRC, 2012, p. 202).

Scientific research catalyzes the emergence of new technological tools and their applications that are developed by engineering design. Science, engineering, technology and their applications have a deep impact on humankind in many fields such as agriculture, communication, transportation, construction, and health care. Advances in science produce new materials, and understanding of processes that may be applied through engineering to produce new technologies. New technology, in turn, provides scientists more opportunities to probe the natural world at a larger or a smaller scale. In many cases, engineering and technology precede science (Petroski, 2010). There are numerous examples from the history of humankind that shows engineering and technology precedes science, especially modern science. Science and engineering affect society and in turn, the politics and needs of society have an influence on the work of scientists and engineers.

Textbook Selection

The selection of the United States chemistry textbooks used in this study is based on the common textbooks used in the local inter-school districts of the city of Houston and many of which are used nationwide (Table 1). The selection of the Indian chemistry textbook is based on the curricular materials designed by the National Council of Educational Research and Training (Table 2). The topics that have been analyzed from the high school chemistry textbooks of India and United States include

1. Biological Chemistry;
2. Chemical reactions and equations;
3. Acids and Bases;
4. Periodic classification of elements; and
5. Hydrocarbons

Instrument and Unit of Analysis

The instrument used to analyze the high school chemistry textbooks from United States and India as shown in Figure 1 has been adapted from the 27-page booklet entitled *Procedures for Conducting Content Analysis of Science Textbooks* (Chiappetta, Fillman & Sethna, 2004). The first section describes the conceptual framework used to define scientific literacy/nature of science. The second section describes the unit of analysis to be categorized in each page of the textbook. The third section provides many practice units to categorize in order to become proficient in coding. The fourth section describes how to determine the percent of agreement between the coders and Cohen's kappa index for computing inter-rater agreement between two coders who are coding similar units in the sample. The instrument has been modified (Figure 1) from its original version to include the interaction of science, engineering, technology and its applications as per the Framework of K-12 Science Education (NRC, 2012).

The unit of analysis in content analysis is an identifiable message or message component. The unit serves (a) as the basis for identifying the population and drawing a sample; (b) on which variables are measured; and (c) serves as the basis for reporting the results (Neuendorf, 2002). The units that will be analyzed in high school chemistry textbooks include:

1. Complete paragraphs;
2. Questions;
3. Pictures, table and figures with caption;
4. Marginal comments and definitions; and
5. Each complete step of a laboratory or hands-on activity.

Units that not are included in the analysis are the following:

1. Incomplete paragraph
2. Pictures, tables and figures without caption;
3. A page with fewer than two analyzable units;
4. Pages that contain only review questions, vocabulary words etc.; and
5. Goal and objective statements.

Validity

Validity refers to the degree to which evidence supports any inferences made based on the data collected using a particular instrument (Fraenkel & Wallen, 2009). The validity of this instrument has been established by the several studies conducted by researchers Garcia (1985), Chiappetta, Fillman, and Sethna (1991, 1993, 2004), Phillips

(2006), Lee (2007) and Brooks (2008) using this instrument since its inception. A thorough check of words and phrases used in the instrument has also helped to ensure its validity. This study involves the examination of five topics in each of the chemistry textbooks from the United States and India with reference to the representation of nature of science. This sample should provide some insights into the reliability of the instrument and any differences experienced with respect to coding of the textbooks.

Reliability

Reliability is defined as the extent to which a measuring procedure yields the same results on repeated trials (Carmines & Zeller, 1979). Reliability is essential for a measurement to be considered valid. When human coders are used in content analysis, this translates as inter-coder reliability or the amount of agreement between two or more coders. A reliability of 0.75 or higher is considered acceptable and a value lower than 0.80 indicates that there exists a disagreement between the coders (Neuendorf, 2002). Reliability needs to be assessed at two stages in content analysis – at the pilot stage and the final stage. The pilot reliability assessment was done using randomly selected subsamples before the actual study begins and the pilot test data will not be included in the final data analysis. The final reliability assessment was conducted on a randomly selected subsample during the complete data collection and represents the performance and agreement of two coders throughout the study.

A variety of coefficients are available for reporting the level of agreement between the coders such as raw percent agreement, Scott's *pi*, Cohen's *kappa*, Krippendorf's *alpha*, Spearman *rho*, and Pearson *r*. Cohen's *kappa* and Krippendorff's *alpha* values accommodate more than two coders at a time. For this study, percent agreement and Cohen's *kappa* will be calculated as indicators of inter-rater reliability. The percent agreement may be computed using the following formula:

$$PAo = A / n$$

PAo represents the proportion of agreement observed; A is the number of agreement between two coders, and n represents the number of units coded that the two coders coded for the test. The statistic ranges from .00 (no agreement) to 1.00 (perfect agreement).

For Cohen's *kappa* to be useful, the following conditions need to be met. They are (a) the units which are coded have to be independent of each other, (b) categories of the nominal scale that are used for rating are independent of each other, mutually exclusive and exhaustive, (c) raters have to work independent of each other. The Cohen's *kappa* value is calculated using the following formula:

$$k = (Po - Pc) /(1-Pc)$$

where k = Cohen's kappa, Po = the proportion of agreement between the two raters, Pc = the proportion of inter-rater agreements which may occur due to chance. A *kappa* value of 1.00 indicates perfect agreement and a value of -1.00 indicates perfect disagreement by chance. Kappa value between 0.50 and 0.70 is considered fair agreement beyond chance and a value below 0.50 is considered poor agreement beyond chance.

Limitations of the Study

Content analysis is limited to the availability of recorded information, in this case, the textbooks. The study cannot be generalized to all other chemistry books and to chemistry books belonging to other Asian countries. The results are limited only to the textbooks analyzed as a part of this study.

<table>
<tr><td>I. Knowledge produced by science and nature of knowledge

A. facts, concepts, laws, or principles
B. hypothesis, theories, or models
C. questions asking recall of information
D. tentativeness and durability of scientific knowledge
E. distinctness of scientific knowledge</td><td>II. Engages students in investigations, science process skills, and reasoning

A. learn through the use of materials
B. learn through the use of charts and tables
C. learn through the use of physical and mental models
D. make calculations
E. participate in a “thought” experiment
F. get information from the internet, library, scientific journals, communication with scientists and other reliable sources
G. use scientific observation and inference
H. analysis and interpretation of data</td></tr>
<tr><td>III. Illustrates the thinking and work of scientists, and the scientific enterprise

A. describes how a scientists discovered or experimented
B. historical development of an idea
C. empirical basis of science
D. use of assumptions
E. inductive or deductive reasoning
F. cause and effect relationship
G. evidence and/or proof
H. presents scientific method(s) or problem solving steps
I. skepticism and criticism
J. human imagination and creativity
K. characteristics of scientists (subjectivity and bias)
L. various ways of understanding the natural world</td><td>IV. Interaction between science and society

A. usefulness of science
B. negative effects of science
C. discussions of social issues related to science
D. careers in science
E. contributions of diversity
F. societal or cultural influences
G. make public or peer collaboration
H. limitations of science
I. ethics in science
J. funding from external agencies to promote growth of science</td></tr>
<tr><td colspan="2">V. Science, Engineering, Technology, and its applications to society

A. Science influences engineering and technology and vice versa
B. Use of sophisticated technology to study science
C. Combined effects of science, engineering, and technology to solve global problems
D. careers in engineering and technology
E. contributions of diversity in engineering and technology
F. societal or cultural influences in engineering and technology
G. limitations of engineering and technology
H. ethics, equity and responsibility in engineering and technology
I. funding from external agencies to support the growth and development of new technology
J. Effects of technology on world of information and knowledge</td></tr>
</table>

Figure 1. Modified themes of nature of science category.

Table 1

High School Chemistry Textbooks used in United States

Textbook	Publisher	Topics
Chemistry – Matter and Change	Glencoe	Biological chemistry; Chemical Reactions; Acids and bases; Periodic table; Hydrocarbons
Chemistry	Prentice Hall	Biological chemistry; Chemical Reactions; Acids and bases; Periodic table; Hydrocarbons
Introductory Chemistry Concepts & Connections (Corwin)	Pearson Prentice Hall	Biological chemistry; Chemical Reactions; Acids and bases; Periodic table; Hydrocarbons
Modern Chemistry	Holt, Rinehart and Winston	Biological chemistry; Chemical Reactions; Acids and bases; Periodic table; Hydrocarbons

Table 2

High School Chemistry Textbooks used in India

Textbook	Publisher	Topic
Science – Textbook for Class X	National Council of Educational Research and Training (NCERT)	Periodic Table Chemical Reactions and Equations Acids and Bases Hydrocarbons
Chemistry Part I Textbook for Class XI	National Council of Educational Research and Training (NCERT)	Classification of Elements and Periodicity in Properties
Chemistry Part II Textbook for Class XI	National Council of Educational Research and Training (NCERT)	Hydrocarbons
Chemistry Part II Textbook for Class XII	National Council of Educational Research and Training (NCERT)	Biomolecules

CHAPTER V

RESULTS AND DISCUSSION

The purpose of the study was to compare Chemistry textbooks used in United States and India with regard to the five themes of nature of science namely: (a) science as a body of knowledge; (b) science as a way of thinking; (c) science as a way of investigation; (d) the interaction between science and society; and (e) science, engineering, technology and its applications to society and also verify whether the five aspects of the nature of science produce an acceptable level of intercoder reliability. By examining the science content used in American and Indian chemistry textbooks it is possible to obtain some idea as to how science and the scientific enterprise is perceived textbooks which are the most prominent instructional materials used in science classrooms of both countries.

The research questions proposed in this study are as the following:

1. What is the balance of the five aspects of nature of science (knowledge, thinking, investigative, interaction of science with society, interaction between science, engineering and technology with society) in high school chemistry textbook from the United States?;

2. What is the balance of five aspects of nature of science (knowledge, thinking, investigative, interaction of science with society, and interaction between science, engineering, and technology with society) in high school chemistry textbook from India?; and

3. What are the similarities and differences in the representation of nature of science in chemistry textbooks used in the United States and India?

The procedure and methods of content analysis used in this study is described in Chapter 4. This chapter presents and discusses the balance of the five aspects of nature of science in chemistry textbooks from both countries. The reliability of the data presented is determined using percent agreement and Cohen's kappa.

Reliability of Coding

Reliability refers to the consistency of coding or inter-rater reliability obtained because of unit coding. Inter-coder reliability or reproducibility is a strong indicator of reliability of content analysis. Inter-coder reliability measures the extent to which content classification produces the same result when the text is coded by more than one coder. In this study, two coders coded the textbooks independent of each other. Both coders were familiar with the five themes of the nature of science and coded several sample units before the actual coding process. Inter-coder reliability of the coded units was measured using percent agreement and Cohen's *kappa*.

The inter-coder reliability of the categorization of the units of analyses for textbooks used in the United States and India is summarized in Tables 3, 4, 5, 6, 7 and 8 respectively. With respect to percent agreement for coding the five themes of the nature of science for textbooks from India (Table 3), the coders achieved 93.06%, 94.52%, 94.56%, 87.25%, 100.0%, 99.04%, and 100.00% percent agreement for the analyzed samples. With respect to the Cohen's *kappa* value, the two coders achieved *kappa* values of 0.86, 0.84, 0.90, 0.92, 0.80, 0.95, 0.54 and 1.00 respectively.

The percent agreement for coding from Corwin textbook (Table 4) is greater than 90.00% for all the samples. The percent agreement for coding from Glencoe textbook (Table 5) is greater than 90.00% for all the analyzed samples. The percent agreement for coding between both coders is greater than 90.00% for all analyzed samples from Prentice Hall (Table 6) except for the sample related to biological chemistry where both coders have 85.57% agreement. The percent agreement for coding from Holt, Rinehart, & Winston textbook (Table 7) is greater than 87.00% for all the analyzed samples. Both coders have greater than 90.00% agreement for all samples from ChemComm textbook (Table 8) except for units related to biological chemistry and hydrocarbons where they have 80.00 and 89.41% agreement.

In addition to percent agreement, Cohen's *kappa* is calculated as an indicator of inter-rater reliability. Percent agreement between two raters may appear to be highly reliable and completely in agreement and does not include agreement by chance. Cohen's *kappa* overcomes this issue as it takes into account agreement occurring by chance. *Kappa* values may range anywhere between -1.00 to + 1.00. A value of + 1.00 implies perfect agreement between two raters, while that of - 1.00 implies perfect disagreement. Typically, a higher *kappa* value is indicative of greater agreement by chance. Kappa values greater than 0.80 indicate excellent agreement, values in the range 0.70-0.80 indicate good agreement, values in the range 0.50-0.70 indicate moderate agreement and less than 0.50 indicate poor agreement.

The *kappa* values for all samples analyzed from NCERT textbooks (Table 3) are above 0.80 except for the topic related to hydrocarbons. The sample related to hydrocarbons has a *kappa* value of 0.54. The low *kappa* value may be attributed to small sample size and clustering of most units within one dimension such as the knowledge aspect of the nature of science.

With respect to the Cohen's *kappa* value, the two coders achieved *kappa* values of 0.81, 0.43, 0.90, 0.76, and 0.72 for samples analyzed from Corwin textbook (Table 4). All samples except for the sample related to biological chemistry have reasonable agreement. The sample related to biological has a 95.15% agreement between both coders but a low *kappa* value of 0.43. The low *kappa* value may be attributed to the clustering of 95.69% of the analyzed units in the knowledge dimension of the nature of science.

The *kappa* values for the samples analyzed from Glencoe textbook (Table 5), both coders achieved 0.89, 0.86, 0.88, 0.86, and 0.89 respectively. There is excellent agreement between the two coders for all the analyzed samples. The *kappa* values for the samples analyzed from the Prentice Hall textbook (Table 6) are 0.87, 0.68, 0.91, 0.84, and 0.85 respectively.

The *kappa* values for the samples analyzed from Holt, Rinehart, and Winston textbook (Table 7), both coders achieved 0.78, 0.76, 0.89, 0.90, and 0.88 respectively.

The *kappa* values for the samples analyzed from ChemComm (Table 8) are 0.89, 0.67, 0.91, 0.82, and 0.93 respectively. Four of the five samples analyzed have excellent agreement and the sample related to biological chemistry has a moderate agreement between the two coders.

Validity of the Study

Validity refers to whether the construct measures what the investigator intends to measure. The validity of the study was accomplished by: (1) choosing random samples from the five chemistry textbooks from the United States and India; and (2) using categories from the framework that correspond to the contextual meaning of the nature of science such as knowledge, investigation, thinking, interaction between science and society and the interaction between science, engineering, and technology with society. The procedure used in this study is based on the procedure used by many researchers such as Garcia (1985), Chiappetta, Fillman, and Sethna (1991a, 1993, 2004), Phillips (2006), Lee (2007) and Brooks (2008).

Table 3

Inter-coder Agreement and Reliability Values for the Analysis of Five Categories of the Nature of Science in NCERT Chemistry Textbooks

Textbook	Topic	Coders	Percent Agreement	Cohen's Kappa
NCERT Grade 10	Acids & Bases	A/B	93.06	0.86
NCERT Grade 10	Chemical Reactions	A/B	94.52	0.84
NCERT Grade 10	Hydrocarbons	A/B	94.56	0.90
NCERT Grade 10	Periodic Table	A/B	87.25	0.80
NCERT Grade 11	Periodic Table	A/B	100.00	0.95
NCERT Grade 11	Hydrocarbons	A/B	99.04	0.54
NCERT Grade 12	Biological Chemistry	A/B	100.00	1.00

Table 4

Inter-coder Agreement and Reliability Values for the Analysis of Five Categories of the Nature of Science in Corwin Textbook

Topic	Coders	Percent Agreement	Cohen's Kappa
Acids & Bases	A/B	97.17	0.81
Biological Chemistry	A/B	95.15	0.43
Chemical Reactions	A/B	100	0.90
Hydrocarbons	A/B	98.88	0.76
Periodic Table	A/B	94.77	0.72

Table 5

Inter-coder Agreement and Reliability Values for the Analysis of Five Categories of the Nature of Science in Glencoe Textbook

Topic	Coders	Percent Agreement	Cohen's Kappa
Acids & Bases	A/B	94.63	0.89
Biological Chemistry	A/B	91.03	0.86
Chemical Reactions	A/B	93.80	0.88
Hydrocarbons	A/B	91.52	0.86
Periodic Table	A/B	93.40	0.89

Table 6

Inter-coder Agreement and Reliability Values for the Analysis of Five Categories of the Nature of Science in Prentice Hall Textbook

Topic	Coders	Percent Agreement	Cohen's Kappa
Acids & Bases	A/B	93.82	0.87
Biological Chemistry	A/B	85.57	0.68
Chemical Reactions	A/B	94.42	0.91
Hydrocarbons	A/B	90.71	0.84
Periodic Table	A/B	90.20	0.85

Table 7

Inter-coder Agreement and Reliability Values for the Analysis of Five Categories of the Nature of Science in Holt, Rinehart & Winston Textbook

Topic	Coders	Percent Agreement	Cohen's Kappa
Acids & Bases	A/B	93.15	0.78
Biological Chemistry	A/B	87.20	0.76
Chemical Reactions	A/B	94.45	0.89
Hydrocarbons	A/B	95.54	0.90
Periodic Table	A/B	93.00	0.88

Table 8

Inter-coder Agreement and Reliability Values for the Analysis of Five Categories of the Nature of Science in ChemComm Textbook

Topic	Coders	Percent Agreement	Cohen's Kappa
Acids & Bases	A/B	93.68	0.89
Biological Chemistry	A/B	80.00	0.67
Chemical Reactions	A/B	94.66	0.91
Hydrocarbons	A/B	89.41	0.82
Periodic Table	A/B	94.81	0.93

Results and Discussions of the Representation of the Five Themes of the Nature of Science in Chemistry Textbooks used in India

The results and discussions of the quantitative analyses of the five themes of the nature of science within the chemistry textbooks from India are given in this section. Table 9 summarizes the findings from the books with regard to the five categories of the nature of science. Figures 2, 3, 4, 5, 6, 7, and 8 provide a more visible comparison of the distribution of the five categories within the units analyzed from the textbooks.

NCERT Grade 10 Chemistry Textbook

Four samples were analyzed from the NCERT Grade 10 chemistry textbook and the samples include topics related to chemical reactions and equations, acids and bases, carbon and its compounds, and the periodic classification of elements. More than 60% of the narrative in the analyzed samples related to chemical reactions and carbon and its compounds, focused heavily on the knowledge aspect of the nature of science. However, only 42% and 46% of the narrative focused on the knowledge aspect of the nature of science from topics related to acids and bases and the periodic table respectively.

The textbook contains a significant amount of facts such as the different types of chemical reactions with examples, reactivity of acids and bases, nomenclature of different types of carbon compounds and chemical reactions such as combustion, oxidation, addition, and substitution reactions. Facts related to the properties and trends of elements in the periodic table are outlined in detail in the unit related to the periodic table.

Chemistry textbooks, in general, are content-driven and textbooks from India bear no exception to this rule. One of the major drawbacks to this approach is that it portrays an inaccurate representation of both science and scientists. Students develop the misconception that both science and the work done by scientists is nothing more than accumulating a vast body of knowledge and assume that scientific research has little room for creativity and imagination. Over emphasis of the knowledge aspect also prompts students to rote memorize all the facts in a unit without any discrimination and this leads to frustration.

It is interesting to note that more than 50% of the narrative from the sample related to acids and bases emphasized the investigative aspect of the nature of science. There are 14 investigative activities from this unit and all the activities are hands-on and verification in nature. For example, one activity involves the addition of dilute sulfuric acid to zinc granules and passing the evolved gas through soap solution. Students are required to make observations such as looking for changes at the surface of zinc granules and the surface of the soap solution. They were urged to repeat the activity with acids such as hydrochloric acid, nitric acid, and acetic acid. Further, students are expected to do this activity after learning the content that acids react with metals to form salt and hydrogen gas.

Less than 20% of the narrative related to chemical reactions emphasize the investigative aspect of the nature of science. About 36% and 32% of the narrative emphasized the investigative aspect for the units related to periodic classification of elements and hydrocarbons respectively.

All samples poorly represent the thinking aspect of the nature of science except for the sample related to the periodic classification of elements. About 18% of the analyzed units related to the periodic table represent the thinking aspect of the nature of science. The sample outlines the historical development of the periodic table beginning with the arrangement of elements in groups of three having similar properties, also referred to as “triads” by Johann Wolfang Dobereiner. A side-panel in the text provides information about the life history of Johann Dobereiner. Further details regarding the arrangement of elements in the order of increasing atomic mass by John Newland is provided in the sample. Every eighth element had properties similar to the first element and the arrangement was referred to as octaves. The text mentions the limitations of the octave arrangement of elements and explains how this led to the further development in the classification of elements.

Details regarding Mendeleev’s contribution to the classification of elements and the early development of the periodic table are provided in the sample. A side-panel credits Mendeleev’s achievements to the efforts of his mother. The text mentions Mendeleev’s thought process regarding the arrangement of elements. 63 elements were already known during Mendeleev’s time and he arranged them carefully based on their properties. The text also credits Mendeleev for leaving gaps in the periodic table for elements that were yet to be discovered and not viewing them as defects.

All samples analyzed in the Grade 10 textbook did poorly in the representation of interaction of science with society. The sample related to the periodic table does not have any unit related to the society aspect of the nature of science. The sample related to chemical reactions provides information about corrosion and the damage caused by corrosion to car bodies, iron railings, ships, bridges and other objects made of iron. Numerous examples relating the importance of pH in everyday life are found in the sample related to acids and bases. The text provides interesting information as to how the low pH of acid rain that flows into river water makes the survival of aquatic life difficult. Examples show the need of specific pH range for the healthy growth of plants, the use of antacids such as magnesium hydroxide (sold commercially as Milk of Magnesia) to neutralize excess acid produced as a result of indigestion, and the use of toothpastes that are basic in nature for cleaning teeth and preventing tooth decay. A side-panel in the text provides interesting example of acid-base neutralization reaction from nature by citing the example of how the acidic and painful sting caused by the herbaceous nettle plant that grows in the wild may be neutralized by the leaf of the dock plant that usually grows nearby. The text also mentions the importance of salt in the country's struggle for freedom from the British rule illustrating the importance of salt in the Indian society.

There are very few units that relate science to society from the sample based on carbon and its compounds. One unit explains as to how the consumption of alcohol affects living beings by slowing the metabolic processes and depressing the central nervous system. The use of organic compounds such as esters in the manufacture of perfumes, soaps, and flavoring agents is mentioned in the text.

There are no units analyzed that relate the interaction between science, technology, and engineering.

NCERT Grade 11 Chemistry Textbook

Two samples were analyzed from NCERT grade 11 textbooks and the samples were related to periodic properties and hydrocarbons respectively. In periodic properties, about 89.50% of the narrative represents knowledge aspect of the nature of science and 10.50% of the narrative represents the thinking aspect of the nature of science. There is no emphasis on the interaction between science and society and the interaction between science, technology, and engineering.

The historical background related to the classification of the elements into various groups and periods is discussed in depth in the sample. Dobereiner's classification of elements into triads and Newlands's law of octaves have been discussed before introducing Mendeleev's life history and his contributions. It is interesting to note that the NCERT book unlike the U.S. textbooks clearly mentions that periodicity is related to atomic number or the electron configuration of elements.

A sample related to hydrocarbons was also analyzed from the NCERT Grade 11 textbook. About 97% of the analyzed units represent the knowledge aspect of the nature of science. The sample contains units that represent the International Union of Pure and Applied Chemistry (IUPAC) nomenclature of three major types of hydrocarbons, namely alkanes, alkenes, and alkynes. In addition, the different physical and chemical properties of the different types of hydrocarbons such as substitution reactions, oxidation reactions, and combustion reactions are explained in detail with numerous examples. About 1.44% of the analyzed units represent the thinking aspect of the nature of science. The sample contains a brief account of the life history and contributions of Friedrich August Kekule, a German chemist. Kekule is known for his immense contributions to the field of structural organic chemistry and for proposing the structure of benzene. Kekule was the first chemist to suggest that carbon atoms may also fuse to form rings instead of long chains. Students have also been informed that a group of polybenzenoid structures have been named as Kekulenes in honor of Friedrich August Kekule.

About 1.20% of the analyzed sample represents the science and society aspect of the nature of science. Several uses of hydrocarbons are outlined in the sample such as the use of liquefied petroleum gas (also known as LPG) and compressed natural gas (also known as CNG) as fuels in households and automobiles. The use of hydrocarbons in the manufacture of polymers such as polythene, polypropylene, polystyrene, and as starting materials of many drugs and dyes are outlined in the text. The use of carbon black produced by the incomplete combustion of hydrocarbons in the manufacture of ink, printer ink, black pigments, and in filters is also mentioned. In addition, the sample mentions the detrimental effects of certain hydrocarbons. Benzene and polynuclear hydrocarbons containing more than two benzene rings fused together are known to exhibit both toxic and carcinogenic properties. These hydrocarbons such as 1,2-Benzanthracene, 3-Methylcholanthrene, and 1,2,5,6-Dibenzanthracene are known to enter human body upon contact causing damage to the DNA and eventually cancer. The text provides the names and structural formulas of several toxic and carcinogenic hydrocarbons. This information is important to students as they become aware of some of the harmful effects caused by chemicals around them.

There are no units from the sample that correspond to the investigative or engineering and technology.

NCERT Grade 12 Chemistry Textbook

The sample analyzed from this book is related to biomolecules such as carbohydrates, proteins, fats, and nucleic acids. Around 96.00% of the coded units correspond to the knowledge component of the nature of science. Of the analyzed narrative, 2.86% corresponds to thinking and 1.43% represents the interaction of science with society as seen in Figure 5.7.

There is no emphasis on the investigative or engineering component of nature of science. More than 90% of the book represents the knowledge aspect of the nature of science. The narrative contains detailed description of biomolecules like carbohydrates, proteins, and nucleic acids. Properties and structural details of biomolecules such as glucose, sucrose, and fructose are also included. The content of the analyzed sample is comparable to college-level biochemistry textbook. There are no investigative activities in the sample. Side-panels within the text inform students about the contributions of Nobel Laureates James Watson and Har Gobind Khorana in the field of Medicine and Physiology. However, there is no information as to details regarding their scientific work. The text also contains brief applications of different biomolecules in everyday life. Interestingly, there is no mention of bioengineering or even genetic engineering in this unit.

Table 9

Percentages of Nature of Science Categories in High School Chemistry Textbooks from India

Textbook	Topic	Coder	Nature of Science Categories				
			Knowledge	Investigation	Thinking	SS	SET
NCERT	Chemical	A	78.20	17.80	1.37	2.74	0.00
Grade 10	Reactions	B	76.71	19.18	0.00	4.11	0.00
		Mean	77.41	18.49	0.69	3.43	0.00
NCERT	Acids	A	38.15	56.65	0.00	5.20	0.00
Grade 10	& Bases	B	45.66	52.02	0.00	2.31	0.00
		Mean	41.91	54.34	0.00	3.76	0.00
NCERT	Periodic	A	45.10	34.31	20.59	0.00	0.00
Grade 10	Table	B	46.08	38.23	15.69	0.00	0.00
		Mean	45.59	36.27	18.14	0.00	0.00
NCERT	Hydrocarbons	A	59.46	31.76	6.76	2.03	0.00
Grade 10		B	61.90	32.65	5.44	0.00	0.00
		Mean	60.68	32.21	6.1	1.02	0.00
NCERT	Periodic	A	89.50	0.00	10.50	0.00	0.00
Grade 11	Table	B	89.50	0.00	10.50	0.00	0.00
		Mean	89.50	0.00	10.50	0.00	0.00
NCERT	Hydrocarbons	A	96.17	0.00	1.91	1.91	0.00
Grade 11		B	98.56	0.00	0.96	0.48	0.00
		Mean	97.37	0.00	1.44	1.20	0.00
NCERT	Biological	A	96.00	0.00	2.86	1.43	0.00

Grade 12	Chemistry	B	95.71	0.00	2.86	1.43	0.00
		Mean	95.86	0.00	2.86	1.43	0.00

Note. SS = Interaction between Science and Society; SET = Science, Engineering, Technology, and its Applications to Society.

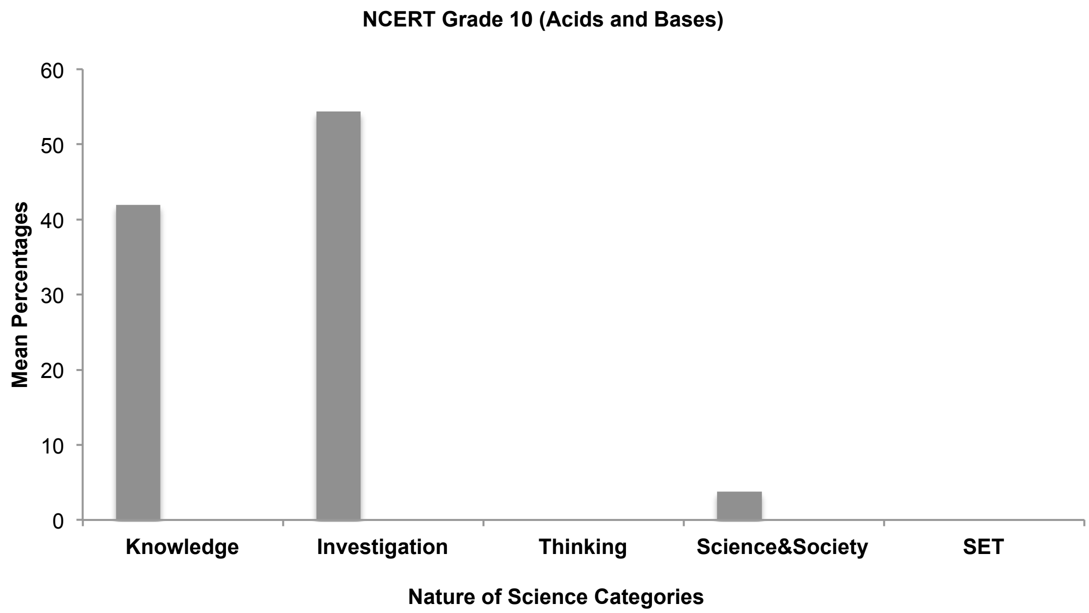

Figure 2. Mean percentages of the representation of the five themes of nature of science from NCERT grade 10 textbook (acids and bases).

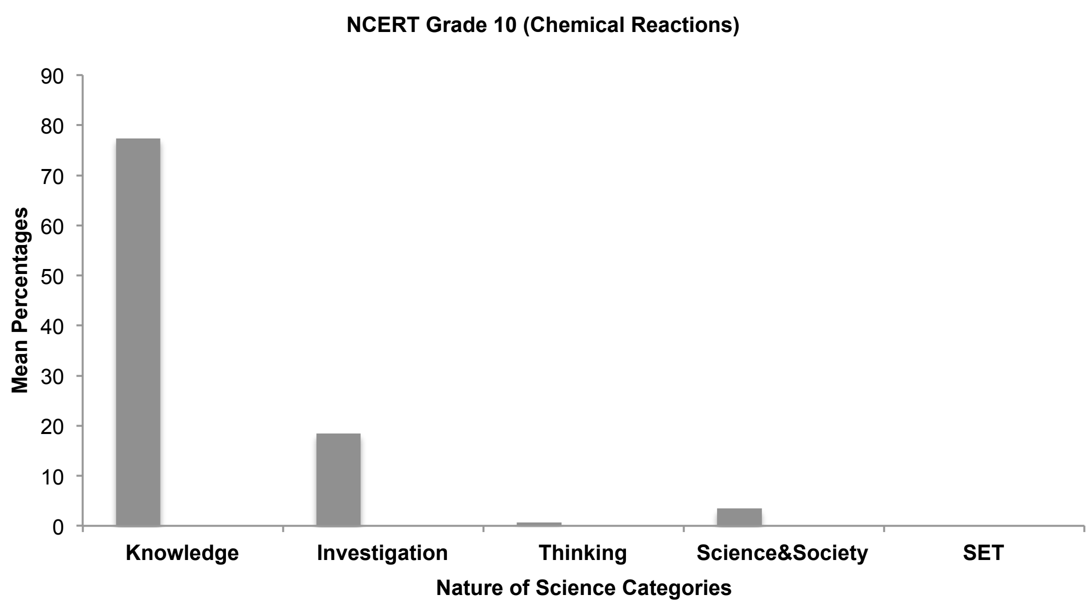

Figure 3. Mean percentages of the representation of the five themes of nature of science from NCERT grade 10 textbook (chemical reactions).

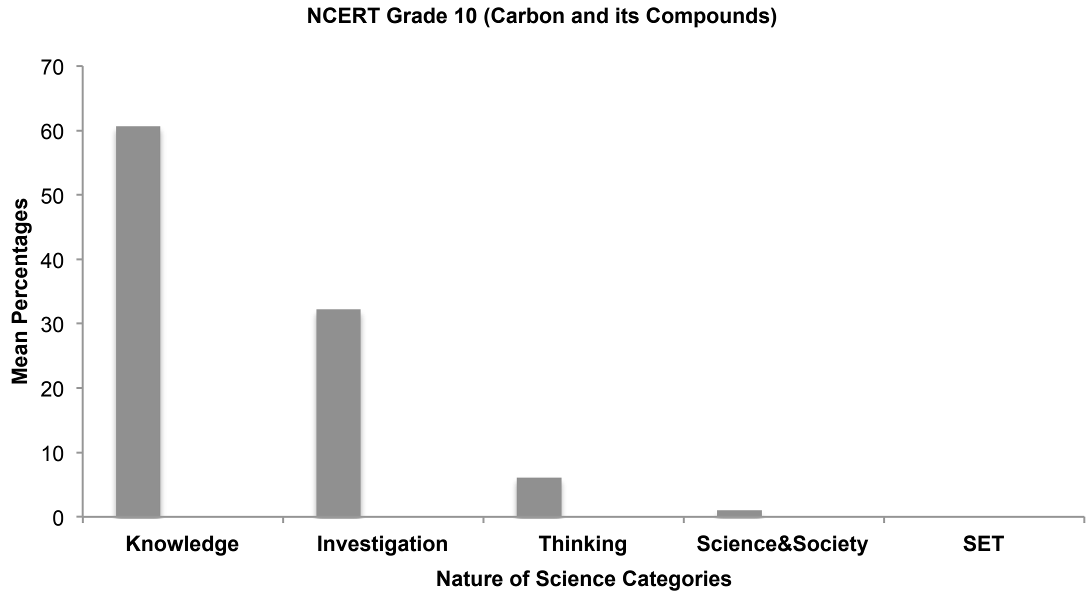

Figure 4. Mean percentages of the representation of the five themes of nature of science from NCERT grade 10 textbook (carbon and its compounds).

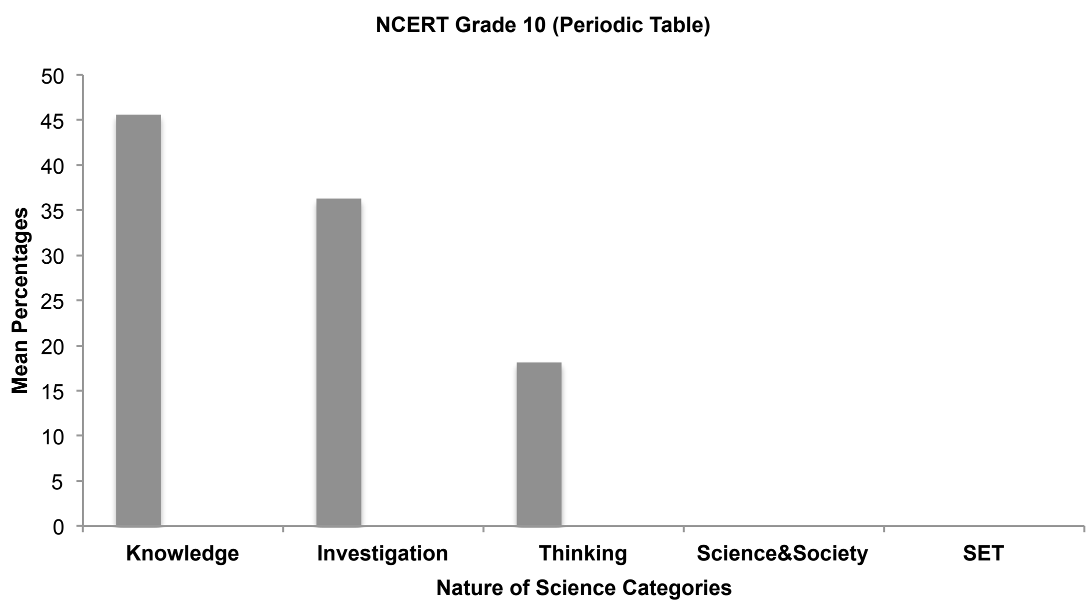

Figure 5. Mean percentages of the representation of the five themes of nature of science from NCERT grade 10 textbook (periodic table).

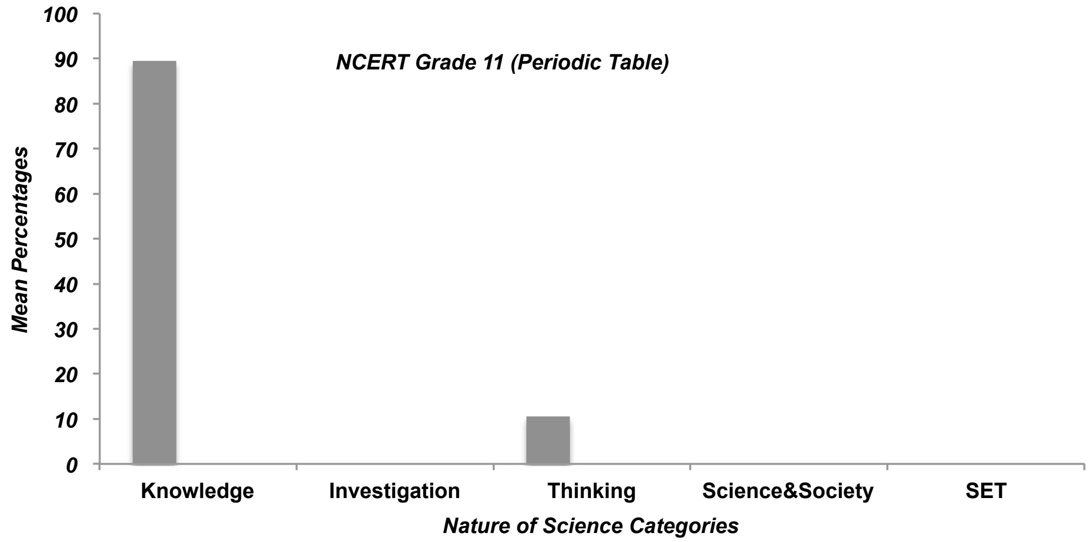

Figure 6. Mean Percentages of the representation of the five themes of Nature of Science from NCERT Grade 11 textbook (Periodic Table)

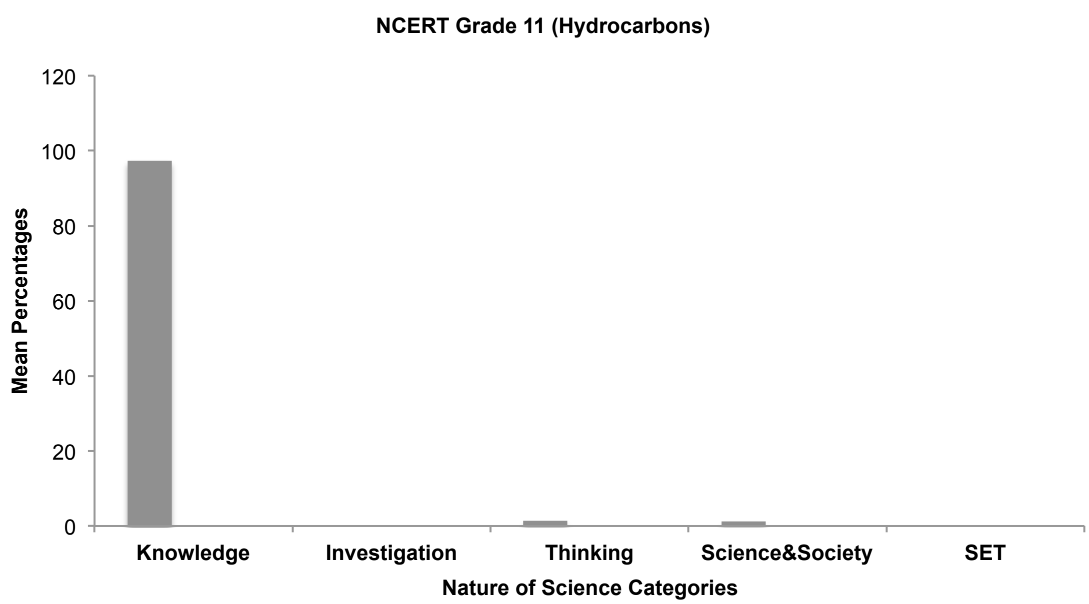

Figure 7. Mean Percentages of the representation of the five themes of nature of science from NCERT grade 11 textbook (hydrocarbons)

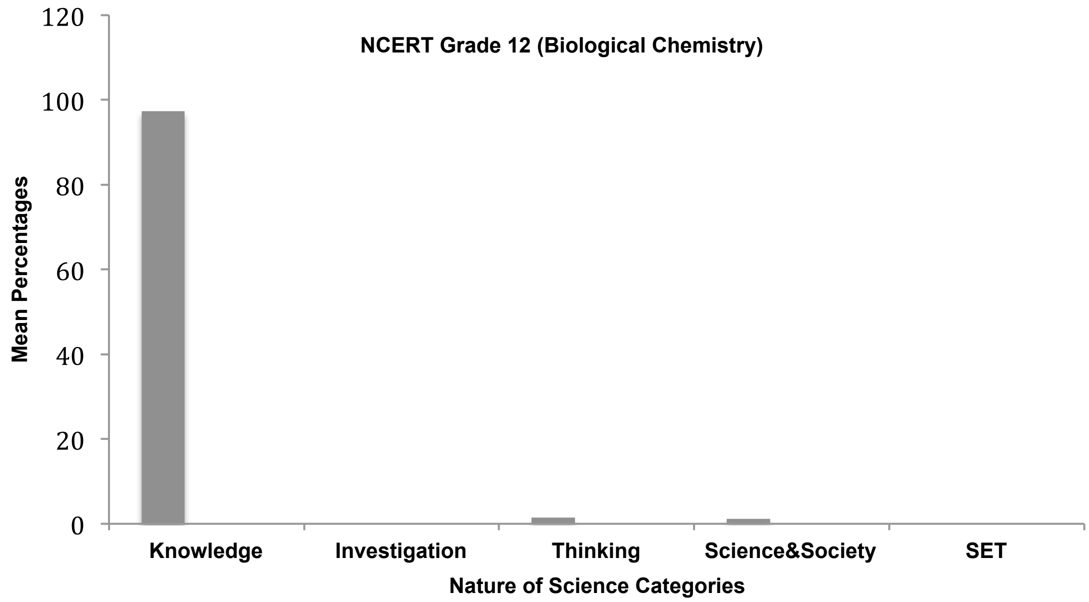

Figure 8. Mean percentages of the representation of the five themes of nature of science from NCERT grade 11 textbook (biological chemistry)

Results and Discussions of the Representation of the Five Themes of the Nature of Science in Chemistry Textbooks used in the United States

CORWIN

The results and discussions of the quantitative analyses of the five themes of the nature of science within the Corwin textbook are given in this section. Table 10 summarizes the findings from the book with regard to the five categories of the nature of science. Figure 9 provides a more visible comparison of the distribution of the five categories within the units analyzed from the chemistry textbook.

About 94% of all the analyzed units represent the knowledge aspect of the nature of science. The sample related to chemical reactions includes detailed discussions regarding classification of different types of chemical reactions such as combination reactions, decomposition reactions, single-replacement reactions and the use of activity series, double-replacement reactions and the use of solubility charts, and neutralization reactions. Each type of chemical reaction is explained with several examples. The sample related to acids and bases provides information regarding classification of substances into acids and bases based on Arrhenius theory and Bronsted-Lowry theory. Information regarding the different types of indicators used to identify acids and bases, detailed calculations on how to find the pH of acidic and basic solutions are also provided in the text.

The chapter related to hydrocarbons mainly focuses on nomenclature of different types of hydrocarbons rather than specific types of chemical reactions of hydrocarbons. Nomenclature of alkanes, alkenes, alkynes, benzene and its derivatives, organic halides, alcohols, ethers, phenols, amines, aldehydes, ketones, carboxylic acids, esters, and amides are discussed. In the sample related to biological chemistry, the structure and properties of the principal biomolecules such as carbohydrates (both mono and disaccharides), proteins, lipids, enzymes, and nucleic acids have been discussed. The sample also contains a brief discussion about protein synthesis.

The sample related to periodic table focuses mainly on periodic trends such as the changes in atomic radii and ionization energy both down a group and also across a period. The text also contains in-depth discussion of electronic configuration of main group and transition metals and the significance of valence electrons and core electrons.

The Corwin textbook is packed with content and closely resembles college level chemistry textbooks. It is possible that a chemistry student due to lack of prior knowledge may suffer from information overload. This is a common occurrence with science textbooks with content overload and usually leads to the frustration of students.

Most of the analyzed samples within the textbook did poorly in the representation of the thinking aspect of the nature of science. However, about 10.42% of the analyzed units from the sample related to the periodic table represented the thinking aspect of the nature of science. The historical perspective towards the development of the periodic table is explained very briefly in the text. Contributions of English chemist Newlands, German chemist Dobereiner, and Russian chemist Dmitri Mendeleev have been explained. A side-panel in the text chronicles the life history and contribution of Russian chemist Mendeleev.

From the sample related to hydrocarbons, the history behind the classification of compounds into organic and inorganic is mentioned in the text. As per the text, when German chemist Friedrich Wohler (1800-1882) heated ammonium cyanate, urea was produced. Wohler's experiment helped disprove the vital force theory and compounds like urea also present in urine of animals was called an organic compound. In the sample related to biomolecules, there is a brief mention of the contributions of Francis Crick and James Watson towards the determination of the structure of DNA. However, there is no mention of the contributions of Rosalind Franklin to the determination of the structure of DNA. The thinking aspect of the nature of science is not represented in any of the units analyzed from the sample related to chemical reactions.

All samples did poorly in the representation of the investigative tenet of the nature of science. Corwin is similar to NCERT grades 11 and 12 textbooks in this aspect as none of the analyzed units represent the investigative dimension. Also the engineering, science, and technology dimension of the nature of science is missing from the book.

Overall 2.28% of all the analyzed units from the five samples represent the science and society aspect of the nature of science. Less than 1% of the analyzed units from the samples related to the periodic table and hydrocarbons represent the science and society aspect of the nature of science. About 3% of the analyzed units from the sample related to acids and bases provide information about the importance of acids and bases in our everyday life. The text provides information to students pertaining the different uses of acids and bases such as the maintenance of acidity in body fluids and blood by an elaborate buffer system, anatacid tablets such as carbonates, bicarbonates, and hydroxides for neutralizing upset stomach problems, and the use of ammonia and sodium hydroxide solutions for various household cleaning purposes. In addition, the text carries a side-panel elaborating the detrimental effect of acid rain on our environment.

About 5% of the analyzed units from the sample related to chemical reactions represent the society aspect of nature of science. The text presents detailed information on some of the common household chemicals, name and formula, and also safety measures while using the chemical. This is definitely very valuable information to students as it provides details regarding various common household chemicals such as Epsom salts, naphthalene, dry ice, hydrochloric acid, and sulfuric acid. In addition, the text also provides interesting information about fireworks by posing a question to students as to whether they have ever wondered how the different colors of fireworks were produced? This section connects chemical reactions and electron configuration to everyday life using the example of fireworks.

Table 10

Percentages of Nature of Science Categories in Corwin

Topic	Coder	Nature of Science Categories				
		Knowledge	Investigation	Thinking	SS	SET
Acids	A	92.96	0.00	4.23	2.82	0.00
&Bases	B	91.98	0.00	4.72	3.30	0.00
	Mean	92.47	0.00	4.48	3.06	0.00
Biological	A	98.17	0.00	0.93	0.93	0.00
Chemistry	B	93.20	0.00	2.91	3.88	0.00
	Mean	95.69	0.00	1.92	2.41	0.00
Chemical	A	94.44	0.00	0.00	5.56	0.00
Reactions	B	95.36	0.00	0.00	4.64	0.00
	Mean	94.90	0.00	0.00	5.10	0.00
Hydrocarbons	A	96.07	0.00	3.37	0.56	0.00
	B	96.63	0.00	2.25	1.12	0.00
	Mean	96.35	0.00	2.81	0.84	0.00
Periodic	A	88.96	0.00	11.04	0.00	0.00
Table	B	90.20	0.00	9.80	0.00	0.00
	Mean	89.58	0.00	10.42	0.00	0.00

Note. SS = Interaction between Science and Society; SET = Science, Engineering, Technology, and its Applications to Society.

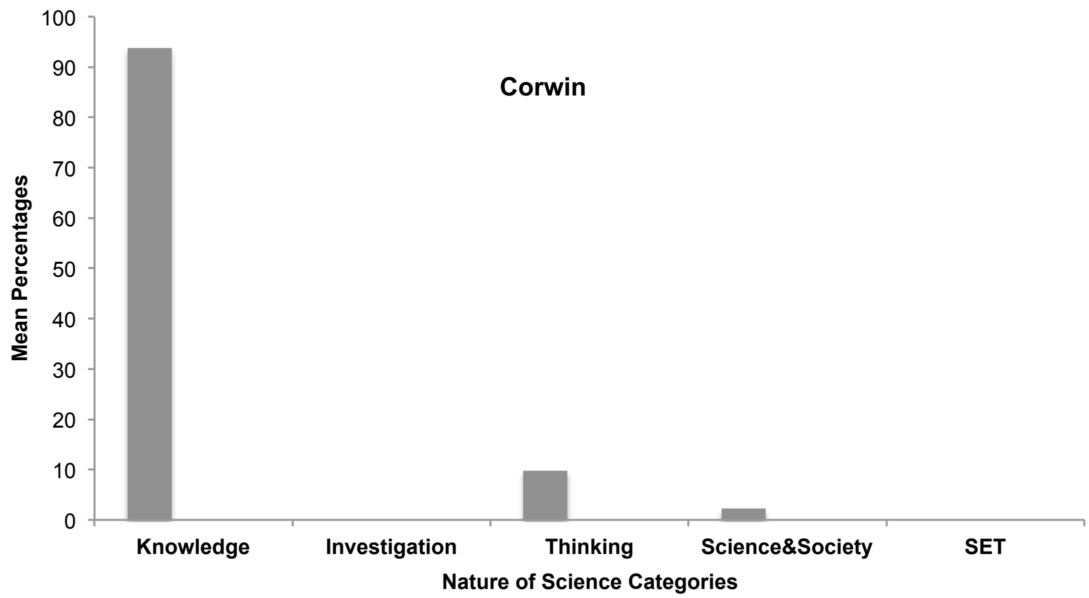

Figure 9. Mean percentages of the representation of the five themes of nature of science from Corwin chemistry textbook

GLENCOE

The results and discussions of the quantitative analyses of the five themes of the nature of science from the Glencoe textbook are given in this section. Table 11 summarizes the findings from the book with regard to the five categories of the nature of science. Figure 10 provides a more visible comparison of the distribution of the five categories within the units analyzed from the chemistry textbook.

More than 50% of the analyzed units from all the samples represent the knowledge aspect of the nature of science. The text is predominantly content laden and present students with vast amount of information as facts, theories, and principles. The sample related to acids and bases provides information related to the different acid-base theories such as the Arrhenius theory, Bronsted-Lowry theory, and Lewis theory. In addition, principles related to strength of acids and bases, pH scale, neutralization reactions, titrations of strong acid-strong base and weak acid-strong base, and hydrolysis of different types of salts is provided in depth. The sample related to biological chemistry focuses on structure and function of the four major types of biomolecules namely proteins, carbohydrates, fats and lipids, and nucleic acids. In addition, the text provides information regarding important metabolic processes such as photosynthesis, cellular respiration, and fermentation.

The sample related to chemical reactions presents students with step-by-step rules for writing and balancing chemical equations by applying the law of conservation of matter. Major types of chemical reactions such as combustion, synthesis, single and double replacement reaction with examples are also discussed in this section. The sample related to hydrocarbons mainly focuses on nomenclature and isomerism (both structural and optical) of the major categories of hydrocarbons such as alkanes, alkenes, alkynes, cycloalkanes, and aromatic hydrocarbons. The sample does not provide any information about chemical reactions of hydrocarbons.

There is a brief discussion related to the development of the modern periodic table. Most of the sample related to periodic table focuses on the trends of different periodic properties such as atomic radii, ionic radii, ionization energy, and electronegativity.

About 13% of all the analyzed units of all samples represent the investigation component of nature of science. All samples contain several short verification labs where students are provided the objective of the lab, and detailed step-by-step procedure. Towards the end of each lab activity, there are several questions that ask students to analyze, explain, and draw inferences based on the observations made during the hands-on activity. For example, the sample related to acids and bases presents students with a hands-on laboratory activity that compares the strength of different acetic acid solutions using a conductivity tester. Students are asked to write the expression of the acid dissociation of acetic acid and compute the percent ionization of the different acid samples. Students are asked to verify their hypothesis based on their observations. Additionally, students are posed with the question as to the need to use large amounts of water for rinsing of acid spills on living tissue.

About 25% of the analyzed units from all samples represent the thinking aspect of nature of science. The sample related to acids and bases contains a flow chart providing the history of acids and bases based on the contributions of chemists, biologists, environmental scientists, and inventors over the past 150 years. Information related to the first antiseptic spray containing carbolic acid to the use of sulfuric acid in plastic production and high-octane gasoline is found in the flow cart. The sample related to the periodic table provides brief information related to the historical development of the modern periodic table, similar to other textbooks analyzed in this study. There are several questions at the end of each section that foster critical thinking skills. For example, students are asked to calculate how many moles of ATP would be produced by a yeast cell both in the presence and absence of oxygen gas. This question requires students to integrate concepts from various units such as stoichiometry, chemical reactions, and cellular respiration.

About 2.30% of the analyzed units from all samples represent the interaction of science with society. The sample related to hydrocarbons focuses on the benefits of hydrocarbons and also provides information on carcinogens such as benzene, toluene, and xylene that were earlier used as laboratory and industrial solvents. The textbook also presents interesting information as to how a methane digester works by converting animal wastes to usable energy. The sample related to biological molecules provides information related to the benefits of biomolecules to human body.

The sample related to the periodic table has a side-panel discussing the career opportunities of research chemists by citing the example of a nuclear chemist. The text mentions how a nuclear chemist works with a large team that includes physicists, engineers, and technicians. It is important to realize that research entails collaboration and sharing of results with the scientific community.

Less than 2% of the analyzed units represent the integration of technology, engineering, and science. The text pages contain side-panels that provide information regarding online resources that provide supplementary information to students. The supplementary resources include online self-check quizzes, web links for research projects, activities, and at home labs. There are no units within the analyzed samples that relate engineering to chemistry.

Table 11

Percentages of Nature of Science Categories in Glencoe

Topic	Coder	Nature of Science Categories				
		Knowledge	Investigation	Thinking	SS	SET
Acids	A	66.37	8.85	22.12	0.88	1.77
& Bases	B	65.47	8.41	24.32	0.30	1.50
	Mean	65.92	8.63	23.22	0.59	1.64
Biological	A	55.56	17.52	23.50	3.73	1.28
Chemistry	B	50.87	16.52	28.70	1.30	2.61
	Mean	53.22	17.02	26.1	2.52	1.95
Chemical	A	58.99	13.31	24.82	1.44	1.44
Reactions	B	58.03	9.85	29.93	0.73	1.46
	Mean	58.51	11.58	27.38	1.09	1.45
Hydrocarbons	A	56.64	12.24	22.38	5.59	3.15
	B	58.10	10.56	24.65	4.23	2.46
	Mean	57.37	11.40	23.52	4.91	2.81
Periodic	A	55.56	17.52	23.50	3.73	1.28
Table	B	51.76	14.57	30.15	1.00	2.51
	Mean	53.66	16.05	26.83	2.37	1.90

Note. SS = Interaction between Science and Society; SET = Science, Engineering, Technology, and its Applications to Society.

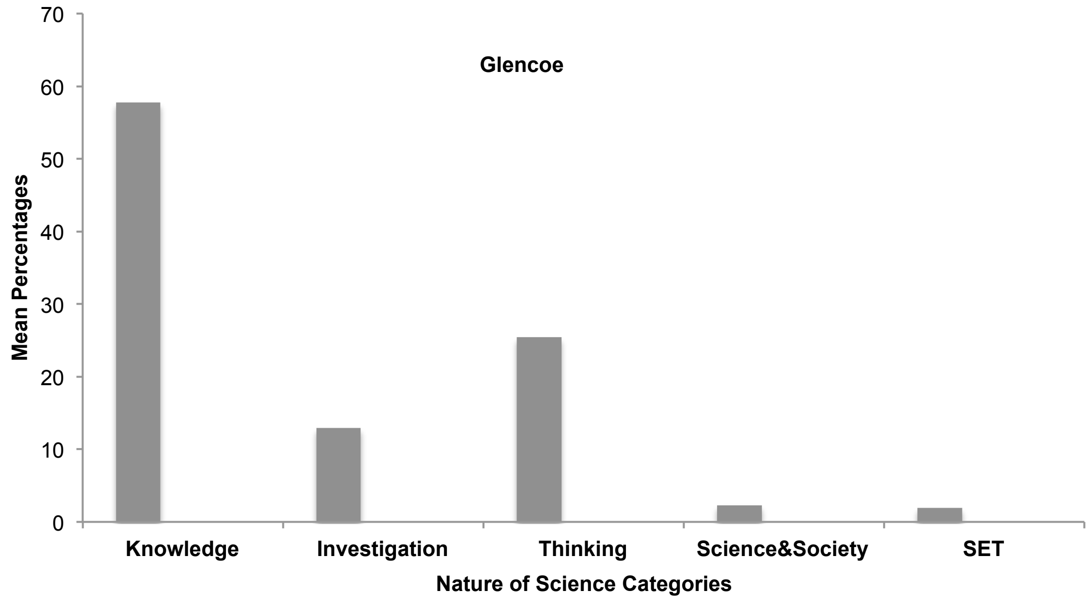

Figure 10. Mean percentages of the representation of the five themes of nature of science from Glencoe chemistry textbook.

PRENTICE HALL

The results and discussions of the quantitative analyses of the five themes of the nature of science from the Prentice Hall textbook are given in this section. Table 12 summarizes the findings from the book with regard to the five categories of the nature of science. Figure 11 provides a more visible comparison of the distribution of the five categories within the units analyzed from the chemistry textbook.

The knowledge component contributes to a majority, around 58.90% of the total units analyzed. Investigation and thinking themes contribute to 12.56% and 26.62% of the analyzed units respectively. Influence of science on society represents 1.40% of the analyzed units and the interaction between engineering, science, and technology represents only 2.00%.

A greater portion of the analyzed units corresponds to the knowledge component of the nature of science. The sample related to acids and bases provides information related to the important acid-base theories like Arrhenius, Lowry-Bronsted, and Lewis theory. In addition, the text provides detailed information related to pH calculations, and determination of strength of acids and bases using titration experimental method. The sample related to biological chemistry discusses the structure and functions of major types of biomolecules such as carbohydrates, lipids, nucleic acids, and proteins. Unlike, most other chemistry textbooks, the text contains information related to the concept of genetic mutation and fundamentals of biotechnology.

Different types of chemicals such as combination, combustion, decomposition, single and double replacement reactions with examples are discussed in the section related to chemical reactions. Nomenclature and isomerism of different types of hydrocarbons is covered in detail in the sample related to hydrocarbons. In addition, the sample also discusses the composition and extraction of hydrocarbons such as natural gas, petroleum, and coal from the earth's crust.

The sample related to the periodic table presents the classification of elements into various groups and periods. The text also contains various facts related to periodic properties such as atomic radii, ionic radii, ionization energy, and electronegativity.

The text is content laden and looks like the authors are definitely focusing on delivery of vast body of information to students. Some questions at the end of each section focus on recall of information. Each unit concludes with a comprehensive overview of all essential facts in the form of a student study guide.

About 12.56% of all the analyzed units represent the investigative theme of the nature of science. The laboratory activities are mainly verification activities that require students to make predictions, analyze, and draw conclusions based on their observations. For example, a hands-on activity from the acid-base sample requires students to measure the pH of various household materials using a natural indicator such as red cabbage juice. Students are required to make observations and classify the household materials as acidic, basic, or neutral. The text does not engage students in any guided inquiry type of activities.

About 27% of all the analyzed units represent the thinking aspect of the nature of science. The sample related to periodic table contains several units that correspond to ideas related to the historical development of the periodic table. Dobereiner's classification of elements into triads and Mendeleev's classification of elements in order of increasing atomic mass is discussed in this section. The text emphasizes how the limitations of Mendeleev's classification of elements prompted British physicist Mosley to rearrange elements in order of increasing atomic number. The text also introduces the role of the International Union of Pure and Applied Chemistry (also known as IUPAC) in the classification of elements into groups and periods. However, "the scientific method" is mentioned and how it accelerated the discovery of new elements. Though details regarding the historical development of periodic table is discussed in the sample, there is no mention that periodicity is a function of atomic theory. Textbooks, in general, fail to mention that Mendeleev was looking for a theoretical basis for the classification of elements besides empirical evidence. Even though theories are subject to changes, mentioning the tentativeness of theories is another facet of nature of science that is often ignored by textbooks.

The text also mentions that scientists used scientific methods and this resulted in the discovery of new elements. It is crucial that teachers clarify the misconceptions of the scientific method in the classroom. It is important that science teachers clarify the misconceptions of the scientific method in the classroom. There is no specific systematic scientific method used to find new elements. Scientific research involves creativity besides factual knowledge and there are as many scientific methods as there are scientists (Fernandez & Worrell, 1991.)

The text also contains section assessment questions that help foster critical thinking skills besides recall of knowledge. For example, students are asked to research and propose structures of polymers that are formed by condensation polymerization. Another example includes one where students are asked to use the concept of Le

Chatelier's principle to explain why few chemical reactions in cells never reach equilibrium.

About 1.40% of the analyzed units represent the interaction of science with society. The benefits of various chemical compounds such as acids, bases, biomolecules, and different types of hydrocarbons such as alkanes, alkenes, alkynes, petroleum, natural gas, and coal are mentioned in the text. The text also contains side-panels that discuss various career prospects in chemistry. The careers of material specialist, stone conservator, and organic chemist are discussed in the samples related to chemical reactions, acids and bases, and hydrocarbons respectively. Students are informed that stone conservators specialize in the restoration in the cleaning and restoration of stone objects. Knowledge of both chemistry and art is required as they often work with both chemists and museum personnel. Relating science to real world career opportunities is yet another important dimension of nature of science.

The interaction between science, engineering, and technology contribute to about 2% of the analyzed units. The sample related to biomolecules discusses the principle and applications of biotechnology or recombinant DNA technology. Recombinant technology involves the cleaving of a DNA chain, and inserting a new piece of DNA into the gap created by the cleavage, and resealing the chain. This technology is used to synthesize proteins, cure genetic disorders, and also used to grow disease resistant plants in agriculture. The sample related to hydrocarbons discusses the engineering aspect of the problems associated with knocking in automobiles and how it can be prevented. Knocking is an issue that can cause overheating, loss of power, and engine damage. Students are informed as to how gasoline's octane rating is a measure of its ability to resist engine knock. Prentice Hall is one of the few chemistry books in the study that connects engineering aspects to real world.

Table 12

Percentages of Nature of Science Categories in Prentice Hall

Topic	Coder	Nature of Science Categories				
		Knowledge	Investigation	Thinking	SS	SET
Acids	A	63.67	15.11	18.35	1.80	1.08
& Bases	B	66.67	12.98	17.89	1.40	1.05
	Mean	65.17	14.05	18.12	1.60	1.07
Biological	A	61.43	10.95	38.76	0.00	3.81
Chemistry	B	68.27	11.06	18.75	0.00	1.92
	Mean	64.85	11.01	28.76	0.00	2.87
Chemical	A	62.63	9.09	24.75	2.02	1.52
Reactions	B	61.00	8.00	28.00	1.50	1.50
	Mean	61.82	8.55	26.38	1.76	1.51
Hydrocarbons	A	57.22	11.23	23.53	2.67	5.35
	B	57.98	9.04	28.19	2.66	2.13
	Mean	57.60	10.14	25.86	2.67	3.74
Periodic	A	45.51	19.87	32.69	1.92	0.00
Table	B	44.65	18.24	35.22	0.00	1.89
	Mean	45.08	19.06	33.96	0.96	0.95

Note. SS = Interaction between Science and Society; SET = Science, Engineering, Technology, and its Applications to Society.

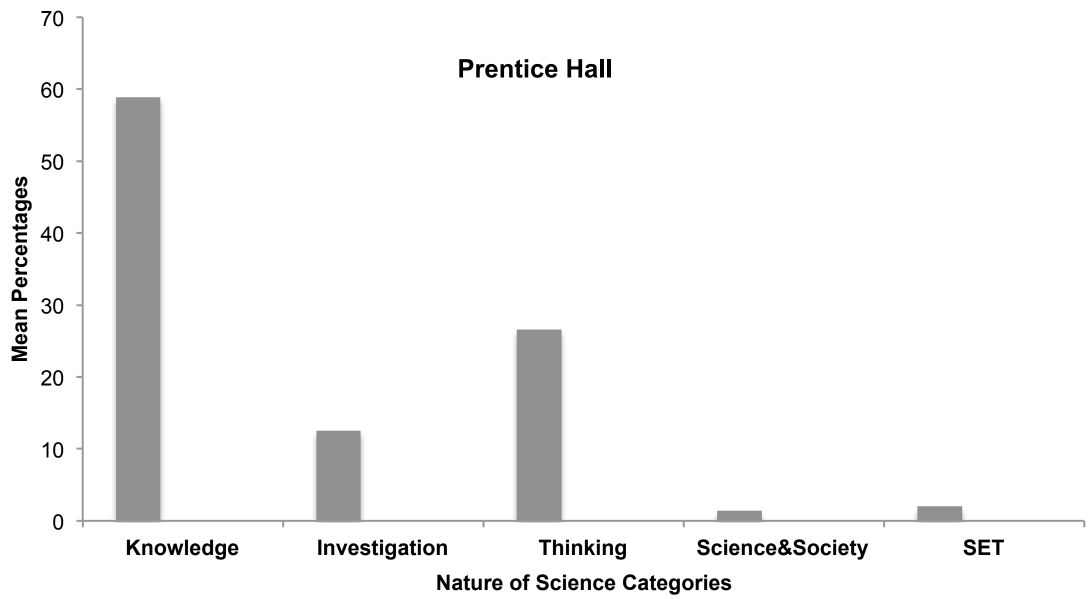

*Figure 11.*Mean percentages of the representation of the five themes of nature of science from Prentice Hall chemistry textbook.

HOLT, RINEHART & WINSTON

The results and discussions of the quantitative analyses of the five themes of the nature of science from the Holt textbook are given in this section. Table 13 summarizes the findings from the book with regard to the five categories of the nature of science. Figure 12 provides a more visible comparison of the distribution of the five categories within the units analyzed from the chemistry textbook.

About 70% of the analyzed units from all the samples in the book represent the knowledge aspect of the nature of science. The sample related to acids and bases discusses the properties of acids and bases with examples, the different acid-base theories, and neutralization reactions. The units analyzed from the sample related to chemical reactions correspond to balancing chemical reactions based on conservation of mass, different types of chemical reactions with examples such as synthesis, decomposition, single and double displacement reactions.

The sample related to the periodic table discusses the historical development of the periodic table and the trends associated with various periodic properties such as atomic radii, ionization energy, and electron affinity. Unlike other chemistry textbooks in this study, the sample also contains discussion related to the physical and chemical properties of elements belonging to the s, p, d, and f block of the periodic table.

The sample related to hydrocarbons focuses on the nomenclature, physical properties, and stereochemistry of alkanes and alkenes. The sample also introduces students to the different functional groups present in organic compounds. In addition, the sample includes a detailed discussion of different types of organic reactions such as substitution, addition, condensation, and elimination reactions. The text related to biological chemistry focuses on structure and properties of the fundamental biomolecules.

The investigative component contributes to about 6% of all the analyzed units from the text. The laboratory activities include a detailed step –by- step procedure and students are expected to interpret and draw conclusions based on their observations. However, some laboratory experiments in the text include a guided inquiry component. For example, the laboratory experiment presented in the sample related to chemical reactions involves the design of a blueprint paper using 10% iron (III) ammonium citrate solution and 10% potassium hexaocyanoferrate (III0 solution. Students are asked to propose a new method to design a blueprint paper. They are also asked to think about some ways by which they can evaluate the efficiency of the procedure and quality of the paper.

The thinking aspect of the nature of science contributes to about 11% of the analyzed units from the sample. The contributions of Dr. Charles Drew, pioneer in the work of blood transfusions, especially in the use of plasma and the development of blood banks has been elaborated in several units from the biological chemistry unit. The history behind the need for blood transfusions and the use of blood plasma as a substitute prompts students to value the contribution of renowned scientists like Dr. Drew to the field of medicine. The questions at the end of the section prompt students to search for synthetic blood substitutes and emphasize the application of science to society. The sample related to the periodic table briefly mentions the contributions of Mendeleev and Mosley to the development of the periodic table. The sample related to hydrocarbons discusses the beginnings of organic chemistry and Friedrich Wohler’s organic synthesis of urea from inorganic materials. Questions at the end of the section foster critical thinking and encourage students to identify materials used in everyday life that an organic chemist may be able to synthesize.

About 6% of all the analyzed units from the text represent the interaction of science with society. The text provides numerous examples of benefits of biomolecules, inorganic acids, and organic compounds such as alkanes, alkenes, and alkynes. The text also contains side panels that describe career opportunities available for chemists. The sample related to the periodic table provides information to students about the career of a material scientist. Material scientists help determine what type of materials should be used in products based on properties and help produce the materials efficiently. The text also mentions the educational credentials required by a material scientist such as a strong background in chemistry, physics, and engineering.

Holt, Rinehart, and Winston is the only textbook in the study with the highest contribution towards the interaction of science, engineering, and technology. About 10.47% of the sample related to biological chemistry corresponds to genetic engineering or recombinant DNA technology, a powerful technique with a variety of applications. Students are exposed to several applications of this powerful process such as DNA fingerprinting to test paternity or heredity. The process of cloning is described citing the example of Dolly, the first animal to be cloned. Applications of genetic engineering such as the synthesis of insulin and growth hormone inform students about some of the current advances in this branch of engineering. The analyzed samples also contain side-panels that provide links to access additional topics in the form of SciGuides using the internet.

Table 13

Percentages of Nature of Science Categories in Holt, Rinehart & Winston

Topic	Coder	Nature of Science Categories				
		Knowledge	Investigation	Thinking	SS	SET
Acids	A	78.94	5.26	2.63	5.26	7.89
& Bases	B	89.47	5.26	2.63	2.63	0.00
	Mean	84.21	5.26	2.63	3.95	3.95
Biological	A	62.70	0.00	8.14	18.60	10.47
Chemistry	B	66.28	0.00	8.14	15.12	10.47
	Mean	66.54	0.00	8.14	16.86	10.47
Chemical	A	69.02	8.70	11.41	4.89	5.98
Reactions	B	69.23	7.14	14.84	3.85	4.95
	Mean	69.13	7.92	13.13	4.37	5.47
Hydrocarbons	A	69.12	12.75	8.33	4.90	4.90
	B	70.30	10.89	6.93	5.45	6.44
	Mean	69.71	11.82	7.63	5.18	5.67
Periodic	A	54.76	7.74	21.43	0.60	11.90
Table	B	62.03	5.70	20.89	0.00	11.39
	Mean	58.40	6.72	21.16	0.30	11.65

Note. SS = Interaction between Science and Society; SET = Science, Engineering, Technology, and its Applications to Society

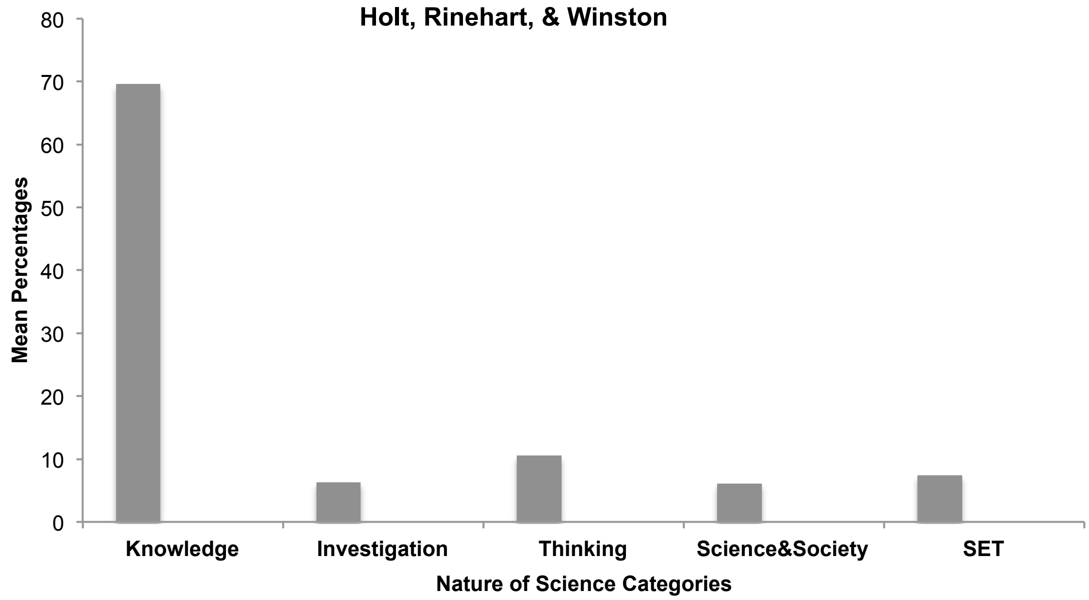

Figure 11. Mean percentages of the representation of the five themes of nature of science from Holt, Rinehart, & Winston chemistry textbook.

CHEMCOMM

The results and discussions of the quantitative analyses of the five themes of the nature of science from the Chemcomm textbook are given in this section. Table 14 summarizes the findings from the book with regard to the five categories of the nature of science. Figure 13 provides a more visible comparison of the distribution of the five categories within the units analyzed from the chemistry textbook.

About 45% of all the analyzed units from the textbook represent the knowledge component of nature of science. The sample related to periodic table discusses the differences between physical and chemical properties of materials, organization of elements in the periodic table and prediction of physical properties of elements. The sample does not include any discussions related to periodic properties such as atomic radii, ionic radii, ionization energy and electron affinity.

The sample related to chemical reactions highlights the need and importance of balancing chemical equations based on the law of conservation of mass. The sample also introduces the mole concept to quantitatively measure matter. Unlike other chemistry textbooks in this study, there is no discussion related to the different types of chemical reactions such as synthesis, combustion, decomposition, single and double replacement reactions.

The sample related to hydrocarbons includes an in-depth discussion related to composition of petroleum and separation of components of petroleum by fractional distillation. The sample includes a discussion of boiling points of alkanes and how structural differences account for differences in boiling points. Boiling point of hydrocarbons is an important physical property that is used in the separation of hydrocarbons from a mixture like petroleum.

The sample related to acids and bases involves discussion of the strengths of acids and bases using the pH scale. The sample related to biomolecules mainly focuses on carbohydrates and fats. It includes discussion related to types and properties of these biomolecules. The sample also includes hydrogenation of fats where carbon double bonds are converted to carbon single bonds in the presence of a catalyst. The text emphasizes the importance of the hydrogenation process in the food industry as it allows food manufacturers to control the consistency and softness of food products such as margarine, vegetable shortening, deep fried foods, and many snack foods.

The investigative theme of the nature of science represents about 19% of all the units analyzed in the text. The laboratory exercises discussed in the text are verification in nature. The lab activity is concluded with several questions where students are asked to make inferences and draw conclusions based on their observations. A laboratory activity from the sample related to chemical reactions involves categorization of elements based on properties such as appearance, conductivity, reactivity with copper (II) chloride, and reactivity with acid. Questions at the end of the section require students to sort and classify elements based on similarities in their physical and chemical properties.

ChemComm is one of the few chemistry textbooks analyzed in this study that encourages scientific thinking amongst students on many issues concerning society such as conservation of resources, dealing with wastes, and recycling of resources. It stimulates students to use their scientific knowledge to address several societal issues and problems and thereby promotes scientific literacy. ChemComm did poorly in the representation of the interaction of science, technology, and society. Less than 1% of the analyzed samples represent this aspect of the nature of science. The sample related to biological chemistry discusses the application of global positioning system (GPS) in farming. GPS may be used to plot areas with great precision in the farmland that require additional fertilizers or any other special treatments.

Table 14

Percentages of Nature of Science Categories in ChemComm

Topic	Coder	Nature of Science Categories				
		Knowledge	Investigation	Thinking	SS	SET
Acids	A	36.78	17.24	39.08	6.90	0.00
& Bases	B	36.21	17.82	40.80	5.17	0.00
	Mean	36.50	17.53	39.94	6.04	0.00
Biological	A	48.25	6.29	38.46	5.59	1.40
Chemistry	B	49.65	18.88	25.87	5.59	0.00
	Mean	48.95	12.59	32.17	5.59	0.70
Chemical	A	55.34	11.17	24.27	9.22	0.00
Reactions	B	55.83	11.17	26.21	6.80	0.00
	Mean	55.59	11.17	25.24	8.01	0.00
Hydrocarbons	A	44.71	27.06	24.71	2.94	0.59
	B	49.41	30.00	17.65	2.35	0.59
	Mean	47.06	28.53	21.18	2.65	0.59
Periodic	A	37.04	26.67	28.89	7.41	0.00
Table	B	40.74	25.19	26.67	7.41	0.00
	Mean	38.89	25.93	27.78	7.41	0.00

Note. SS = Interaction between Science and Society; SET = Science, Engineering, Technology, and its Applications to Society.

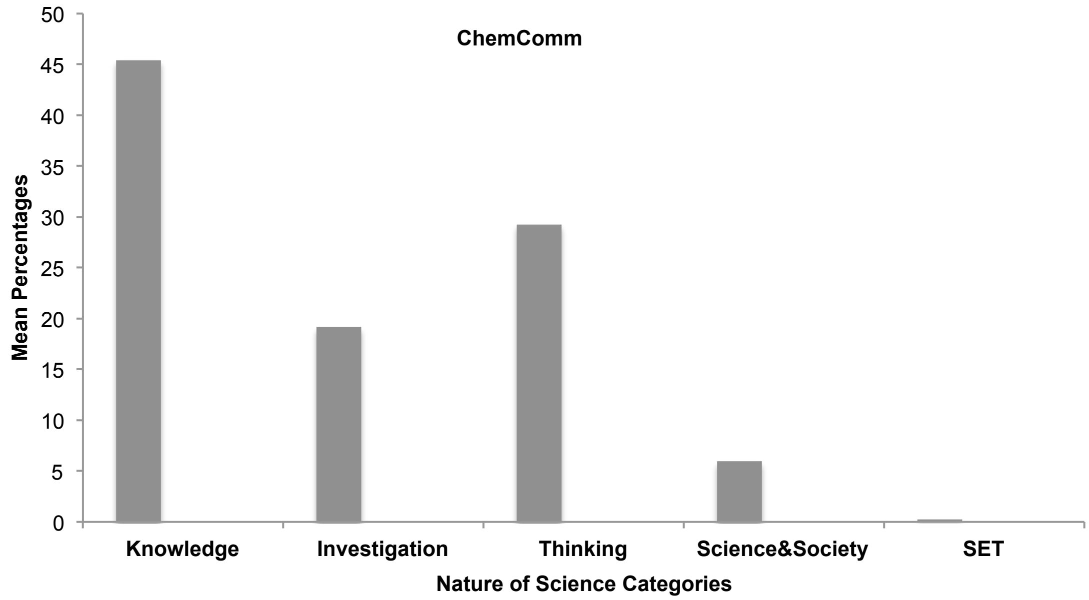

Figure 12. Mean percentages of the representation of the five themes of nature of science from ChemComm chemistry textbook.

Chapter VI

Conclusions And Implications

The purpose of this study was to compare chemistry textbooks from the United States and India with regard to five themes that are related to the of nature of science namely: (a) science as a body of knowledge; (b) science as a way of thinking; (c) science as a way of investigation; (d) the interaction between science and society; and (e) science, engineering, technology and its applications to society. The research technique called content analysis was used in this study to achieve the purpose. Content analysis is a quantitative approach used for making replicable and valid inferences from data to their context (Krippendorf, 1980, p. 20). Five samples pertaining to various topics such as acids and bases, biological chemistry, chemical reactions, hydrocarbons, and the periodic table were chosen from high school chemistry textbooks from the United States and India.

To ascertain the reliability of the results, two coders analyzed the units from selected samples of textbooks from both countries. Both coders were familiar with the five themes related to nature of science, and they coded independent of each other. The coders coded samples as a part of the pilot study before they began the coding of the actual samples from textbooks used in India and the United States. The inter-coder reliability was established using percent agreement and Cohen's *kappa* values. The *kappa* values for majority of the samples are well within the acceptable range, except for two samples. The sample related to hydrocarbons from NCERT Grade 11 textbook has a *kappa* value of 0.54 and the sample related to biological chemistry from the Corwin chemistry textbook has a kappa value of 0.43. The low *kappa* values are attributed to clustering of most units within one theme such as knowledge aspect of the nature of science. However, the high percent agreement between both coders illustrates the results of the coding to be reliable.

The four themes or categories related to the nature of science is based on the framework developed by Collette and Chiappetta (1984) and employed by many other researchers such as Brooks (2008), Lee (2007), Phillips (2006), Chiappetta, Sethna, and Fillman (1991, 1993, 2004) and Garcia (1985) who reported reliable and meaningful findings with respect to using the themes to identify how science textbooks present science to students. This study includes an additional theme related to the nature of science and this includes the interaction between science, engineering, and technology. The fifth theme was proposed based on the new Framework for K-12 Science Education (NRC, 2012) which advocates the inclusion of engineering and technology education in science classes from K-12.

The Nature of Science in Chemistry Textbooks from the United States and India

Five topics were analyzed from five different high school chemistry textbooks: acids and bases, biological chemistry, chemical reactions, hydrocarbons, and the periodic table. The presentation of five chemistry topics with respect to the five themes nature of science was not balanced because of overrepresentation of the knowledge and investigation themes. The knowledge component represented by all the textbooks was related to facts, theories, and laws that seem to be information overload. The investigative activities were the cookbook type, which not encourage critical thinking. Though inquiry has been promoted by science education reform documents of the past, the science textbooks analyzed in this study do not promote a minds-on approach to learning high school chemistry. Samples analyzed from textbooks such as Corwin did not have any investigative type of activities and focused primarily on learning vast amount of information.

The overall representation of how scientists have gone about their work to establish chemistry from all samples analyzed from the United States textbooks is approximately 20%. Samples analyzed from ChemComm, Glencoe, and Prentice Hall represent about 25% of the thinking aspect of the nature of science. These samples included both historical development of scientific ideas and critical thinking questions at the end of each section. However, samples analyzed from Corwin and Holt, Rinehart, and Winston had only 10% representation of the thinking aspect of the nature of science.

The interaction of science with society was represented in most books. In Holt, Rinehart, and Winston, 16.86% of the analyzed units represented the societal aspect of the nature of science from the sample related to biological chemistry. About 5.94% of all the analyzed from the ChemComm textbook represent the interaction of science with society theme of the nature of science. ChemComm bears the distinction of being one of the few textbooks that gives importance to the societal aspect of the nature of science. The samples analyzed from ChemComm discuss several societal issues related to the extraction of metals from various mineral resources. The authors make an earnest effort to promote scientific literacy amongst students.

The interaction between science, engineering, and technology is represented poorly in most textbooks. There is less than 10% representation of this aspect of nature of science in the analyzed textbooks from the United States. In Holt, Rinehart, and Winston 10.47% of the analyzed units from the sample related to biological chemistry represent the interaction between science, engineering, and technology. The analyzed sample carries a detailed description of the processes employed in biotechnology and genetic engineering.

Topics related to acids and bases, biological chemistry, chemical reactions, periodic table and hydrocarbons were analyzed from NCERT Grades 10, 11 and 12 textbooks used in India. The topics chosen were similar to topics chosen from the United States textbooks which included topics related to acids and bases, biological chemistry, chemistry reactions, hydrocarbons, and the periodic table. The representation of the five themes related to the nature of science was unbalanced in all the analyzed topics with the knowledge component ranked the highest among the five analyzed themes with more prominence in grades 11 and 12 textbooks. 82% of the analyzed samples represent the knowledge component in the Indian textbooks compared to the 65% of the samples used in the United States chemistry textbooks. More than 95% of the analyzed units from grade 11 and 12 textbook samples were related to the knowledge component compared to grade 10 textbook samples. Indian students participate in a mandatory board examination at the end of grade 12 and the scores obtained are crucial for admission to professional programs such as medicine, engineering, and other undergraduate degree programs. This probably could be the reason as to why there is a significant emphasis on science as a body of knowledge in order to prepare students for admission to different competitive programs. The knowledge component in samples pertains to facts, theories, and principles and encourages rote memorizations. Some of the analyzed samples like hydrocarbons and biomolecules are similar to college level chemistry textbooks in terms of the difficulty of the content.

Investigations in the form of verification activities were present in samples from grade 10 textbooks, however, they were completely absent from grades 11 and 12 textbook samples. Several investigative activities (about 2-3 activities per page of the sample) related to chemical reactions and acids and bases were found in grade 10 textbook. The activities adopted the format where students did experiments to verify a principle or law completed in lecture and answered several questions at the end of the experiment to confirm the findings. The activities did not promote any knowledge construction as an aspect of good inquiry nor did it encourage critical thinking.

The Indian chemistry textbooks did poorly in the thinking component of the nature of science or how scientists construct and verify knowledge. Less than 6% of the analyzed units in the samples correspond to this aspect of the nature of science. However, 10.50% of the sample related to periodic table from grade 11 chemistry textbook and 18.14% from the grade 10 chemistry textbook correspond to the thinking aspect of nature of science. The sample contains in depth discussions related to the historical development of the periodic table and clearly mentions that the chemical and physical properties of elements are attributed to electron configurations and the atomic number of elements. There are no units or problems within the analyzed samples that promoted inductive or deductive reasoning.

The Indian textbooks also did poorly in the representation of interaction of science with society and the interaction between science, engineering, and technology. Less than 2% of the units analyzed from all samples represented the interaction between science and society and none of the samples analyzed represented the interaction between science, engineering, and technology. It is interesting to note that engineering is a very popular profession by choice of most students from the country but textbooks hardly mention any aspect of this field. Introduction of engineering will help in reinforcing the concepts learned in the science class and illustrate the real world connection between science and mathematical concepts. The Indian textbooks unlike the US counterparts did not discuss any available career opportunities available to students of science in the STEM fields. Only simple examples related to everyday life where discussed and there was no mention of any major research institutes in the country where innovative research is conducted in fields of science and technology.

Implications

The results of this study highlight the shortcomings of chemistry textbooks in conveying an appropriate balance to teaching and learning chemistry. Because the need for a scientifically literate society is crucial, especially considering the fact that United States is a key player and contributor in the global economic field, it is important to produce better chemistry textbooks. The record shows that United States students have shown mediocre performance in science and mathematics compared to students from many Asian countries in student assessment of mathematics and science such as Program for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMS). It is critical to improve STEM literacy and encourage students to learn and think deeply about science, engineering, and mathematics.

The understanding of science and the workings of the scientific enterprise have been a goal and concern for more than 100 years by science educators. Unfortunately many science teachers may not know how to plan their instruction to achieve a better balance of the five themes of nature of science especially in improving the STEM literacy in the upcoming years. The results of this study clearly indicate that even though chemistry textbook publishers and authors may be familiar with the many aspects of NOS, they have long ways to go to achieve balance in presenting science.

The emphasis of the knowledge component ranks the highest in textbooks from both India and the United States. Chemistry is a content – packed subject where majority of the teachers tend to use material directly from the textbook in their classroom teaching. The use of textbook instruction of this type is bound to be focused on science as a body of knowledge with little emphasis on the other components such as thinking, interaction of science on society and the interaction between science, engineering, and technology. The fundamental issue in chemistry instruction is the obsession of teaching large amounts of content especially in countries like India where every page of the textbook contains a large amount of facts, principles, and theories. The content in these textbooks resemble college level information and hence classroom instruction is focused on the delivery of content rather than helping students to build knowledge in a meaningful manner. High school chemistry textbooks resemble college level texts especially in the number of pages. Consequently, a content-dense textbook may easily overwhelm students who may not be able to distinguish between pertinent versus trivial information and who will most likely engage in rote memorization to pass tests and examinations.

Most teachers and students view learning as absorption of vast amounts of facts and principles with little emphasis on building critical thinking skills. Students in many science classes might be science literate but not necessarily scientifically literate. Most students may not be aware as how the facts and concepts learned in the science class may be applied in the real world. Textbook authors and publishers need to be aware that textbooks should not portray science as merely a vast body of scientific knowledge but should make a more conscious focus on the other facets of the NOS. Science teacher education programs also need to emphasize the importance of nature of science in science education so that prospective teachers will be able to make meaningful decisions in the classroom rather than blindly relying on the textbook for classroom instruction. Teachers may need to go beyond the textbook and provide examples to emphasize the thinking aspect, and interaction of science, engineering, and technology with students in the classroom. It is important for authors and publishers to include inputs from both classroom teachers and science educators while writing textbooks. However, science education reformers, teachers, textbook authors, and publishers seem to work mutually independent of each other. This needs to change and science teachers, and textbook authors need to work as a team to drive the changes and provide quality science instruction to students.

Future Research

The use of electronic media such as iPads, laptops, Kindles, etc. in classrooms have become increasingly popular in recent times. Content analysis methodology is not restricted to printed material like textbooks or newspapers but may be used also to evaluate the quality of electronic instructional tools. A possible future direction may be to evaluate the extent by which the five themes of nature of science are portrayed in electronic instructional tools such as eBooks, apps on iPhones and iPads, and supplementary instructional materials in the form of CDs and DV

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Appendix A

Chemistry Practice Analysis

Read each unit of analysis, or paragraph, and determine which of the five categories (1 = information, 2 = investigation, 3 = thinking, 4 = interaction of science and society, and 5 = interaction between science, engineering, technology and its applications). For additional help, refer to figure 1 for the list of categories.

1. Johann Wolfgang Dobereiner studied as a pharmacist at Munchberg in Germany, and then studied chemistry at Strasburg. Eventually, he became a professor of chemistry and pharmacy at the University of Jena. Dobereiner made the first observations on platinum as a catalyst and discovered similar triads of elements which led to the development of the Periodic Table of Elements. (National Council of Educational Research and Training. (2009). *Science – textbook for class X*. New Delhi: National Council of Educational Research and Trainin, p. 80)

2. The element carbon occurs in different forms in nature with widely varying physical properties. Both diamond and graphite are formed by carbon atoms, the difference lies in the manner in which carbon atoms are bonded to one another. In diamond, each carbon atom is bonded to four other carbon atoms forming a rigid three-dimensional structure. In graphite, each carbon atom is bonded to three other carbon atoms in the same plane giving a hexagonal array. One of these bonds is a double-bond, and thus the valency of carbon is satisfied. Graphite structure is formed by the hexagonal arrays being placed in layers one above the other. (National Council of Educational Research and Training. (2009). *Science – textbook for class X*. New Delhi: National Council of Educational Research and Training, p. 61)

3. You have learnt in your previous classes that sour and bitter tastes of food are due to acids and bases, respectively, present in them. If someone in the family is suffering from

a problem of acidity after overeating, which of the following would you suggest as a remedy – lemon, juice, vinegar or baking soda solution? (National Council of Educational Research and Training. (2009). *Science – textbook for class X*. New Delhi: National Council of Educational Research and Training, p. 17)

4. The increased pressure that scuba divers experience far below the water's surface can cause too much oxygen to enter their blood, which would result in confusion and nausea. To avoid this, divers sometimes use a gas mixture called heliox – oxygen diluted with helium. Helium's high ionization energy ensures that it will not react chemically in the bloodstream. (Buthelezi, T., Dingrando, L., Hainen, N., Wistrom, C., & Zike, D. (2008). *Chemistry: Matter and change*. Columbus, Ohio: McGraw-Hill/Glencoe, p. 192)

5. A biochemist is a scientist who studies the chemical processes of living organisms. A biochemist might study functions of the human body or research how food, drugs, and other substances affect living organisms. For more information on chemistry careers visit glencoe.com. (Buthelezi, T., Dingrando, L., Hainen, N., Wistrom, C., & Zike, D. (2008). *Chemistry: Matter and change*. Columbus, Ohio: McGraw-Hill/Glencoe, p. 308)

Answers and Explanation

Unit 1 belongs to category III (science as a way of thinking).

The main idea in this unit is the discussion related to the historical development of the periodic table.

Unit 2 belongs to the category I (science as a body of knowledge).

The main idea in this unit is to provide the reader facts related to carbon and its allotropes, diamond and graphite.

Unit 3 belongs to category I (science as a body of knowledge).

The purpose of the question in this unit is to help students recall information related to acid-base reactions such as neutralization which they have learnt in the previous year chemistry course.

Unit 4 belongs to category IV (interaction of science and society).

The purpose of this unit is to indicate the usefulness of helium gas in scuba diving. This unit illustrates one of the many uses of science to society.

Unit 5 belongs to category IV (interaction of science and society).

This unit illustrates the available career opportunities in science to students. The unit describes the job description of a biochemist that requires knowledge of chemistry to perform work-related tasks.