Chapter Two
Literature Review
The Theoretical Underpinnings of Scientific and Technological Literacy

2.1. Orientation to the Chapter

There are a variety of conceptions as to what constitutes scientific and technological literacy. The assortment of conceptions of the two concepts will be unveiled in this literature review. Specifically, this chapter will analyze and trace the evolution of the assortment of conceptions of scientific and technological literacy. Further, it will attempt to accentuate the differences between the two concepts where possible. This chapter will commence with an examination of the underlying concepts of science and technology; proceed to discuss a wide range of perspectives of the two concepts of scientific and technological literacy; and then explain the necessity for scientific and technological literacy. The concepts of scientific and technological literacy will be discussed together as they are inextricably linked. However, there will be a deliberate attempt to define each of these two concepts relative to this study.

2.2. An examination of the underlying concepts of Science and Technology

As mentioned above, in attempting to explore some of the assortment of conceptions of scientific and technological literacy, the underlying concepts of science and technology will be examined. Indeed, a great deal of confusion reigns about scientific and technological literacy and this stems largely from the confusion that exists about science and technology. Sparkes (1996) asserts that science and technology are often equated, and this could be attributed to the fact that it is quite common for people to talk about science and technology as if it was one thing with a double-barreled name. The same author attributes this apparent haziness between science and technology to common features that the two terms share, but more importantly because of neglect and the repeated use of the term science and technology.

The equating of science and technology is a universal trend. In South Africa, we have been swaying between making a clear distinction and conflating the two disciplines for the past six years. There were two distinct factions prior to the election of a democratic government in 1994. One of the groups wanted to confer subject or learning area status on each of the two entities while the other group, Kahn (1994), advocated for the two entities to be combined. With the advent of the outcomes-based curriculum paradigm (C2005) in 1997, the government accorded technology the status of a learning area. However, Chisholm et al (2000) recommended that technology be subsumed under the umbrella of science once again. Unfortunately, the Minister of Education, together with the Council of Education Ministers and Cabinet, declined to incorporate technology under science (Potenza 2000).

The recommendation by Chisholm et al (2000) resonates with a finding of UNESCO (1983) where science and technology tended to be paired in the literature to such an extent as to imply some indissoluble bond between them, as though they connoted a single entity. The way in which UNESCO (1983) distinguishes between science and technology is to separate out the purposes of the two activities.

"The purpose behind a scientific activity is to build up knowledge: to give an explanation for something; to provide a true description of some event, to diagnose the nature of some condition. The purpose behind a technological activity is to facilitate human aspiration: to solve some practical problem; to put knowledge to good use, to extend the boundaries of existing possibilities" (UNESCO 1983:17). For example, the explanation of how an electrical circuit functions is a scientific activity but the use of such information to design a two-way switch is a technological activity.

Stahl (1994:44), similar to UNESCO (1983), maintains that "technology addresses the desire for devices in the production of commercial products and appliances. It is much influenced by human demand but is also highly susceptible to the power of capital... On the other hand, science addresses the endless human quest for knowledge of self and the surroundings... Science serves our intellectual needs, not our material needs. In contrast to technology, the pursuit of science depends entirely on altruism through public and private resources. Any so called "pay-off"- other than pure knowledge – involves a conversion into technology, the passage from idea to device or product."

UNESCO (1983:18) contends that "science and technology are not identical. They are interdependent but contrasting activities. The role of science is to enlighten humanity. The role of technology is to use the existing knowledge to serve humanity."

Herschbach (1995, cited in Ntshingila-Khosa 1998:1) traced the etymology of the word technology as being 'reasoned application', a reasoned application of technological knowledge. There is a distinct difference between the Herschbach (1995) interpretation of the word technology and that proposed by UNESCO (1983) presented above. The latter contends that it is science that generates knowledge, and that technology is the application of that knowledge. Thus, the use of the concept technological knowledge by Herschbasch (1995) becomes confusing when trying to dissect out the differences between science and technology. Nonetheless, the concept of technological knowledge became more meaningful when the author traced the evolution of the word technology. The earliest conceptions of technology placed emphasis on conceptual material, e.g. understandings, knowledge, decision making, etc. This early conception of technology blends in with the Herschbach (1995) understanding of the word technology. An elaborated discussion on the early conceptions of technological literacy features below (see sub-section 2.3.4. pp.34-40).

Brookes et al (1994) took the Herschbach (1995) concept of reasoned application one step further. Brookes et al (1994) envisioned technology as the study of how to manipulate or organize the environment to enable people to do what they need and want to do. This interpretation intimates that a set of experiences or a body of knowledge is necessary to manipulate and organize the environment. However, the translation of the theory into successful manipulation or organization of the environment is not necessarily spontaneous. This study will examine the extent to which the body of knowledge or scientific literacy is applied successfully in everyday life.

The Brookes et al (1994) definition begs a further question that was pursued by Naughton (1990). The latter enquired whether technology is necessarily the application of scientific knowledge because he believed that technology did not necessarily involve the exclusive application of scientific knowledge. For example, it is common sense that the design of a car requires scientific data like aerodynamics. However, the task cannot be accomplished without other kinds of knowledge as well. These other kinds of knowledge include how the driver feels about driving the car, and how the driver responds to the car's appearance. Thus, other kinds of knowledge like experience, craft knowledge and feelings about a particular product are also vital to the technologists. In short, science is not the exclusive factor in technological design.

Naughton (1990:9) accordingly defined technology as the "the application of scientific and other knowledge to practical tasks by organizations that involve people and machines." The element of practicality in Naughton's definition stems from addressing real life situations. The "other knowledge" has been explained above. The use of the words people and machines in the definition is because technology is a complex interaction between people and social structures on the one hand, and machines on the other.

Yet another dimension of technology is manifested in its interpretation as process. In the United Kingdom (UK), technology was introduced as a compulsory component of the education of all children within the state system (Shield 1996, cited in Ntshingila-Khosa 1998). This approach was intended to improve the competitiveness of the nation but its rationale has been questioned by Custer (1995, cited in Ntshingila-Khosa 1998) as he describes the UK government's intervention as a partial understanding of a complex subject. Shield (1996, cited in Ntshingila-Khosa 1998) adds that insufficient attention has been given to technology as doing as well as understanding. In South Africa, we had a similar initiative to the UK in that the Technology 2005[2] (T2005) team, which subscribed to the conception of technology as a problem-solving process (see Rogan et al 1998:10, T2005, National Evaluation Study, Gauteng Province Final Report), and designed technology materials for Grade I learners. However, Reddy (1998) argues that this integration of technology into the life-skills curriculum could lead to technology being sidelined or diluted. While materials were designed by the National T2005 team, the members of the T2005 Gauteng Task Team (GTT) are very explicit that technology cannot be narrowly defined vis-à-vis' life-skills nor technical subjects like woodwork. This broader conception of technology implicit in the GTT interpretation creates the impression that technology is a complex concept like curriculum, and cannot be defined by one of its features, like syllabus is oftentimes incorrectly used to define curriculum.

The above review of the underlying concepts of science and technology was intended to create a backdrop to an examination of the perspectives of the concepts scientific and technological literacy which will now be elaborated upon.

[2] The Draft National Framework for Technology 2005 (DOE 1996b) defined the T2005 project as a three-year curriculum development program that aimed to develop:

- a National Curriculum Framework for Technology Education in the compulsory school phases;
- appropriate pre- and in-service Teacher Education programs in technology education for compulsory phase teachers; and
- systems for implementation and evaluation of the Technology 2005 project in the participating provinces.

According to Reddy (1998), the initial role of the T2005 team was to explore the feasibility of implementing T2005, but it has developed into a curriculum development and training project.

2.3. The Evolution of the concepts of Scientific and Technological Literacy

In the perspectives on scientific and technological literacy that follow there is widespread acceptance that a variety of interpretations of the two concepts co-exist. Also glaringly evident in the literature, is the evolution of the concepts from rather basic interpretations of lexical knowledge of science, to sophisticated and comprehensive versions of the two concepts. For example, the concept of scientific literacy has evolved through phases of practical literacy and civic literacy Shen (1975, cited in Shamos 1995), cultural literacy (Hirsch 1997, cited in Zuzovsky 1997) and functional literacy, and then to a multidimensional construct (Eisenhart, Finkel and Marion 1996, cited in Bybee 1997). After reviewing the literature on the two concepts of scientific literacy and technological literacy, it is the author's best understanding that the concept of scientific literacy spawned that of technological literacy. Thus, in early times (1930s to 1970s) the concept of scientific literacy predominated. Thereafter, the concept of technological literacy was almost implicit in scientific literacy and only later on (1980s) did technological literacy acquire independent status, although the two terms are still used interchangeably as are the concepts of science and technology.

Each of the variations of the concepts of scientific and technological literacy will be discussed below. Moreover, in the following summary of perspectives on scientific literacy, the viewpoints of different academics (Shamos 1995; Charp 1996 & 1999; Fensham 1995 & 1999; Baarah & Volk 1994; Doke 1998; Bauer 1992; Bybee 1995 & 1997; DeBoer 1999; Jenkins 1999; De Vos and Reiding 1999; Laugksch 2000; Kolstoe 2000; Eilks 2000; Parkinson 1999; Cross & Price 1999; Hand et al 1999; and Hanharan 1999) are juxtaposed within the framework of a core set of ideas of the two concepts presented by Zuzovsky (1997). The latter was by far one of the most coherent presentations of the evolution of the two concepts.

Zuzovsky (1997:232) asserts that "scientific and technological literacy remain vague terms which are defined and interpreted in many different ways. Early definitions refer mostly to the ability of individuals to read about, comprehend and express an opinion on scientific and technological matters." Zuzovsky (1997) provides a comprehensive analysis of the two concepts from the 30s through to the 2nd World War and then in the 80s and 90s. An abbreviated version of the chronological analysis of Zuzovsky (1997) follows. Each of these phases of evolution of the two concepts as perceived by Zuzovsky (1997) will be embellished with the perspectives of other writers as well as those of the author.

2.3.1. Scientific Literacy in the 30s

Zuzovsky (1997:232) contends that "during the 30s, scientific literacy was conceived as the unique contribution of science to general education, a tool for developing desirable thinking habits such as open-mindedness, intellectual integrity, observation and interest in testing one's own opinions (Dewey, 1934)." The author's first reaction to this early interpretation of scientific literacy was that it was characterized by a distinct element of generality, with a focus on non-science specific (general) knowledge and an overwhelming silence on the use of scientific knowledge in society. However, Shamos (1995) disproves the author's assertion as he states that Dewey believed that high school science education should accomplish more than merely prepare the student in a practical way for eventually playing a useful role in society. In fact, because of the influence of writers like Dewey in the twentieth century, science education "was justified more and more on the basis of its relevance to contemporary life and its contribution to a shared understanding of the world on the part of all members of society" (DeBoer 1999:583).

Bybee (1997) also provided a chronological overview of the concept of scientific literacy but differs with Zuzovsky (1997) in that Bybee's (1997) research concluded that Conant first used the term scientific literacy in 1952. Bybee (1997) adds that Conant (1952) used the term scientific literacy to denote a broad understanding of science. It is apparent that other writers, like DeBoer (1999) and Laugksch (2000), concur with the 1950's origin of the term scientific literacy. DeBoer (1999:582) states quite explicitly that "scientific literacy is a term that has been used since the late 1950s to describe a desired familiarity with science on the part of the general public." Laugkscb (2000:72) adds that "the term scientific literacy was coined in the 1950s."

It is important at this juncture to note that the concept of scientific literacy may also be defined as public understanding of science, as intimated in the latter part of DeBoer's (1999) statement above. Other labels that are used synonymously with scientific literacy include "citizen science" (Jenkins 1999:704). Laugksch (2000) used a geographical basis to separate the different labels of the concept because the term scientific literacy is more common in the United States, while public understanding of science is more widespread in Britain (and other parts of Europe), and another way of describing scientific literacy is "la culture scientifique," which is a term used in France.

Regardless of when the term scientific literacy was first used, it is clear that early interpretations are fingerprinted by simplistic interpretations of scientific literacy. These early interpretations embrace a factual knowledge of science, which is used to develop what Shamos (1995) referred to as scientific habits of mind or scientific attitude, which is a rational or logical way of thinking that is supposed to be an outcome of being a scientist. Incidentally, Shamos (1995) and Miller (1983, cited in Shamos 1995) believed that the concept of scientific attitude, which was developed by Dewey, triggered the scientific literacy movement.

With the outbreak of the Second World War in 1939, there was a lull in the refinement of the concept of scientific literacy. In fact, only in the 1950s was the concept of scientific literacy resurrected and revisited as discussed below.

2.3.2. Scientific Literacy after the 2nd World War

Zuzovsky (1997:232) asserts that "after the 2nd World War, there was a demand for knowledge that would enable citizens to become more aware of science-related issues, so that in a democratic society, they would have the power to affect public and technological policy. This demand often referred to as 'civic literacy' was defined by Benjamin Shen (1975)." Shen (1975, cited in Shamos 1995) referred to the civic literacy as the last cornerstone of informed public policy. Shen (1975, cited in Shamos 1995) believed that the aim of scientific literacy is to enable the citizen to become more aware of science and science-related issues so that he and his representatives can bring their common sense to bear upon these issues. Interestingly, this concept of civic literacy seems to have gained momentum again in the 1990s through the concept of "citizen science, i.e. science which relates in reflexive ways to the concerns, interests, and activities of citizens as they go about their everyday business" (Jenkins 1999:704).

As mentioned above, Bybee (1997) insisted that Conant was the first to use the concept of scientific literacy in 1952. Bybee (1997) adds that in the early 1950s, the term scientific literacy was often associated with discussions of general education in science. Bybee (1997) states that Hurd was the first person to use the term scientific literacy as a major theme for science education in 1958. The Hurd interpretation of scientific literacy was an understanding of science and its applications to social experience, and science was integral to economic, political and personal issues. It is imperative to understand the context within which this resurgence in the interest in scientific literacy emerged in 1958. In 1957, the Russians launched Sputnik, the first ever earth satellite, and this caused much embarrassment for the Americans and compelled them to reform their curriculum. The reform of the curriculum in America entailed a strong, cognitive centered curriculum with science being a core subject to cultivate the mind. The American President's Commission on National Goals (1960) "gave top priority to science, mathematics..." (Ornstein & Hunkins 1988:156) and the focus on subject matter was supported by legislation to provide training and resources in the associated subjects.

The 1960s can best be described as the era of sloganeering in the evolution of the concept of scientific literacy as the concept tended to be used as a major educational aim (Roberts 1983, cited in Bybee 1997). Among those cited as using scientific literacy as a slogan are Fitzpatrick (Policies for Education 1960), Kusch (Education for Scientific Literacy in Physics 1960), Johnson (The Goals of Science Education 1962), and Wittlin (Scientific Literacy in the Elementary School 1963) [Bybee 1997]. Other interesting developments in the 1960s provided by Bybee (1997) included Hurd's (1963) definition, which emphasized the knowledge of key science concepts, relating these concepts in a coherent way, the social relevance of science, and the limitations of science. Another interpretation of scientific literacy emerged from Koelsche (1963, cited in Bybee 1997) who viewed the concept as the knowledge and skills required to read and understand science as presented in the media. Also, Shamos (1963, cited in Bybee 1997) characterized scientific literacy in the 1960s as knowing science in a humanistic way or feeling comfortable in reading or talking with others about science in a non-technical way. Interestingly, in subsequent articles, Shamos asserted that scientific literacy is essentially unachievable for most people (see sub-section 2.3.3. pp.21-34). Laugksch (2000) contends that in 1962, Snow made a contribution to the development of the term scientific literacy. The author finds it difficult to accept Snow's contribution because Snow drew a distinction between literary intellectuals and scientists, and did not really attempt to define scientific literacy.

Bybee (1997) also provided details on a very significant scientific literacy development in the mid-1960s. Bybee (1997) cites the Pella, O'Hearn and Gale (1966) study that examined one hundred articles to determine what science educators meant by the term scientific literacy. They reported the six most frequent referents:

1. interrelations between science and society; 2. ethics of science; 3. nature of science;
4. conceptual knowledge; 5. science and technology; and 6. science in the humanities.

They found that the primary purposes of scientific literacy were to prepare scientists, to provide the background for careers in technical occupations, and to provide general education science background for effective citizenship. They concluded that the greatest emphasis in science education should be on the latter of the three purposes of scientific literacy. Pella (1967, cited in Bybee 1997) then went ahead and defined scientific literacy using the referents listed above. This was the last development in the evolution of the concept of scientific literacy in the 1960s.

In the 1970s, following on the Pella et al studies (1966, cited in Bybee 1997), "scientific literacy, as the relationship between science and society, gained additional prominence when the National Science Teachers Association (NSTA) identified it as the most important goal of science education…" DeBoer (1999:588). The NSTA defined a scientifically literate person as "one who uses science concepts, process skills, and values in making everyday decisions as he interacts with other people and his environment, and understands the interrelationships between science, technology and other facets of society, including social and economic development…The aim of a science-technology-society curriculum was to give students knowledge about the science/society interface and the ability to make decisions about science-related science issues" (ibid).

According to Bybee (1997), there were three more significant developments in the evolution of the concept of scientific literacy in the 1970s. These contributions were made by Agin (1974), Showalter (1974) and Shen (1975). Agin (1974, cited in Bybee 1997) published a framework for scientific literacy based on a review of the literature. He proposed six broad categories – science and society, the ethics of science, the nature of science, the concepts of science, science and technology, and science and the humanities – to aid in planning interdisciplinary teaching units, describing each and providing examples of topics and units. Showalter (1974, cited in Bybee 1997) took the process one step further and proposed seven dimensions on scientific literacy – the nature of science, concepts in science, processes of science, values of science, science and society, interest in science, and the skills of science. Showalter and his colleagues believed that these dimensions represented a continuum along which individuals progressed. Hurd also made two appearances in the 1970s with his concept of scientific enlightenment (1970), a new term for scientific literacy, and with his vision for Science, Technology and Society as well as an interdisciplinary emphasis (1975). The works of Shen (1975, cited in Shamos 1995) are elaborated below, as his conceptions of scientific literacy are the predecessors of conceptions of scientific literacy that emerged in the 1980s.

2.3.3. Scientific Literacy in the 80s and 90s

Zuzovsky (1997) goes on to discuss the change in the 80s and 90s in the goals of science education from focusing on the preparation of elite future scientists to the preparation of users and appliers of scientific knowledge, and how this led to a new type of scientific and technological literacy: cultural literacy. This component of the chapter will examine the following concepts: cultural literacy, functional literacy, Branscomb's interpretation of scientific literacy, true scientific literacy, the Project Synthesis definition of scientific literacy, and various interpretations of multidimensional scientific literacy.

As mentioned above, Shen (1975, cited in Shamos 1995) engineered the concept of civic scientific literacy. He also developed a precursor concept to that of civic and cultural scientific literacy, namely practical scientific literacy. According to Bybee (1997), practical scientific literacy included the kind of scientific and technical knowledge that can immediately be put to use to help to solve practical problems. Laugksch (2000:77) cites Shen (1975) and adds that practical scientific literacy is "knowledge that addresses the most basic human needs related to food, health and shelter."

Cultural literacy envisioned a grasp of "basic information needed to thrive in the modern world" (Zuzovsky 1997:232), something that was then translated into possession of a lexicon of scientific terms. Laugksch (2000:80) cites Hirsch (1987) who described the cultural literacy as "the oxygen of social discourse…Hirsch, together with two colleagues, identified about 5000 terms and phrases that …constitute the contents of cultural literacy in the social and natural sciences." Shamos (1995) unpacked this oxygen of social discourse when he defined cultural scientific literacy as a grasp of certain background information communicators must assume their audiences already have, this is the hidden key to effective education. The weakness of cultural scientific literacy according to Shamos (1995) is that if all one needed to be scientifically literate were basic information or vocabulary then we could become scientifically literate by rote. Shamos (1995) added that people who are classified as culturally literate may be able to recognize the science terms used in the media, but for most, their knowledge of science ends there.

Closely tied to the concept of cultural scientific literacy, was an interpretation of scientific literacy developed by Hazen and Trefil (1990, cited in Laugksch 2000). They believed that "a scientifically literate person should be able to place the news of the day about science in a meaningful context" (ibid:80). The similarity of the their interpretation with cultural literacy lies in the fact that rather than select terms and phrases, as Hirsch did, to define the contents of scientific literacy, they "selected 18 general principles of science that cover a range of topics from absolute zero to X-rays" (ibid). At this juncture it is important to emphasize that while cultural literacy, and its ally, proposed by Hazen and Trefil (1990, cited in Laugksch 2000), seem to be a content-oriented and thus unfavourable, the importance of content must not be underestimated. Indeed, as pointed out by Taylor & Vinjevold (1999) one of the greatest weaknesses of many of our teachers is their low levels of conceptual knowledge. Kolstoe (2000) in his attempts to teach science for citizenship focused on two distinct kinds of science knowledge that we need to engage with. First, knowledge about science in the making, or "frontier science," and second, textbook science or "ready made science" (ibid:650). I contend that if we know the latter, it is a start to better teaching. But, if we know them both, it will, for example, help to raise consciousness about disagreements in science. Enough said about the merits of content, let's return to the discussion of cultural literacy.

This cultural literacy definition came under heavy criticism according to Kliebard (1989, cited in Zuzovsky 1997) and another term "functional literacy" emerged. Functional literacy was similar to Shen's (1975, cited in Shamos 1995) civic literacy. It is viewed as the level of understanding science and technology needed to function minimally as citizens and consumers in our society. Shamos (1995) believed that functional scientific literacy requires that individuals transcend the command of a science lexicon, and are able to converse, read and write coherently. The concept of functional scientific literacy is very similar to the Bork's (1999) conception of literacy as a basic competency in a given area; the primary example is reading literacy, the ability to read at a functional level.

Alongside the ongoing discussion about cultural and functional literacy in the 1980s, Laugksch (2000:77) provides yet another contribution to the development of the concept of scientific literacy from Branscomb in 1981, namely, "the ability to read, write, and understand systematized human knowledge." This interpretation of scientific literacy led to eight different categories of scientific literacy, like professional, journalistic or science policy literacy. Clearly, the multidimensional approach to scientific literacy was beginning to be expressed in the multiple foci of both functional literacy, as espoused by Miller (1983, cited in Shamos 1995), and Branscomb's (1981, cited in Laugksch 2000) interpretation of the concept.

For functional literacy, Miller (1983, cited in Shamos 1995) indicated three requirements – not only the mastery of basic vocabulary, and the understanding of science processes, but also the understanding of the impact of science and technology on society and an active, intelligent involvement in public science policy debates. There were two interesting developments that emerged from Miller's three requirements.

First, Arons (1983, cited in Laugksch 2000) included Miller's three requirements in a collection of twelve attributes of a scientifically literate person that he considered important. Arons (ibid:78) focused on the ability to "correctly apply scientific knowledge and reasoning skills to solving problems and making decisions in their personal, civic, and professional lives." Yet again, it is clearly noticeable how the definitions were becoming all inclusive, which indicates the evolution of the concept of scientific literacy towards multidimensionality.

Second, Shamos (1995) argues that Miller's interpretation of scientific literacy is an oversimplification of the concept as everyone knows some facts of nature and has some idea of what science is about. Shamos (1995) is more inclined to levels of scientific literacy as defined by the following three interpretations of the concept which build upon one another. The three interpretations are cultural, functional and true scientific literacy.

Shamos (1995) contends that true scientific literacy entails that the individual actually knows something about the overall scientific enterprise. He or she is aware of some of the major conceptual theories that form the foundations of science, how they were arrived at, and why they are widely accepted, how science achieves order out of a random universe, and the role of the experiment in science. Shamos (1995) accepted that this definition of scientific literacy puts science beyond the reach of many educated individuals.

Perhaps a definition of scientific literacy that is within the reach of all of us is that offered by Baarah & Volk (1994). The latter contend that the scientifically literate person understands how science, technology and society influence one another, and is able to use this knowledge in everyday decision making. Baarah & Volk (1994) adapted this interpretation of scientific literacy from the American Association for the Advancement of Science - AAAS (1989) and Yager & Harms (1981).

Baarah & Volk (1994) also explored the comprehensive definition of scientific literacy that was generated by Project Synthesis in the early 1980s. The purpose of Project Synthesis was to "examine the countenance of science education as it exists at the pre-college level and to make basic recommendations regarding future activities in science education" (Karl and Harms 1981, cited in Baarah & Volk 1994:9). In defining the ideal state of science education, the researchers of Project Synthesis began with the assertion that there are four broad goals that justify the inclusion of science in the school program. The goal clusters describe the scientifically literate person as:

a) *One who can utilize science for improving his/her own life and for coping with an increasingly technological world;*
b) *One who can deal responsibly with science related society issues;*
c) *One who can acquire the scientific and technological knowledge appropriate for his/her academic needs; and*
d) *One who has an awareness of the nature of basic and scope of a wide variety of science and technology related careers open to students of varying aptitudes and interests.*

(Baarah & Volk 1994:10)

The four goal clusters are thus (1) Personal Needs, (2) Societal Issues, (3) Academic Preparation and (4) Career Education/Awareness. Thus science education, as operationalized by Project Synthesis Goal Clusters, incorporates far more than traditional content-laden instruction. Instead, it reflects a strong general education approach. That is, the Project Synthesis Goal Clusters describe an educational thrust that might be deemed appropriate for all citizens. Eisenhart, Finkel and Marion (1996, cited in Zuzovsky 1997) further emphasized the ability to use scientific and technological knowledge. They viewed scientific literacy as a blend of the ability to act (not merely to know) and the promise of widespread use. Literate persons not only possess knowledge, but they use knowledge in varied contexts and for worthwhile purposes and in a socially responsible way. The ability to use knowledge and act involves the:

a) *understanding of how science related actions impact the individuals who engage in them,*
b) *understanding the impact of decision on others, the environment and the future;*
c) *understanding the relevant science content and methods; and*
d) *understanding the advantages and limitations of scientific approach*

(Eisenhart, Finkel and Marion 1996, cited in Zuzovsky 1997:233).

Scientific and technological literacy thus became a multi-dimensional construct (Miller 1983, cited in Shamos 1995). In trying to describe the complexity of this construct, Scribner (1986, cited in Zuzovsky 1997) offered three different metaphors to capture the different meanings of scientific and technological literacy: 1) Literacy as adaptation – refers to what others called functional literacy; 2) Literacy as power- refers to literacies that enable individuals or groups to claim a voice and place in society; and 3) Literacy as state of grace represents the self-enhancing potential of literacy, the special virtues attributed to literate persons. She suggested "ideal literacy" to be the "simultaneously adaptive, socially empowering and self enhancing" kind.

There were three other interesting interpretations of scientific literacy that emerged in the mid-1990s. The first interpretation was developed by an advisory committee set up by the minister of education in the Netherlands to introduce public understanding of science as a subject in its own right. As mentioned above, scientific literacy is sometimes equated to the public understanding of science. The advisory committee affirmed the multidimensional nature of the concept of public understanding of science. They described the concept of public understanding of science as a vision of "all citizens…(having) some idea of the origin, nature and impact of scientific knowledge…these citizens should also have insight into a scientists activities, e.g. designing and using models, developing theories, and carrying out experiments. Moreover, they should be aware of the important scientific and technological aspects of many political and social decisions in our society" (De Vos and Reiding 1999:713).

This interpretation of scientific literacy, or public understanding of science, is very similar to Shamos's (1995) concept of true scientific literacy. Shamos (1995) spoke about the foundations of science, how they were arrived at, and why they are widely accepted, etc. Therefore, this interpretation of science, might, as Shamos (1995) accepted for true scientific literacy, be beyond the reach of many educated individuals.

The second interpretation of scientific literacy in the mid-1990s came from Fensham (1995:36) who contends that scientific literacy, according to TIMSS, includes "the residue of conceptual learning, contextualized in real world situations, and reasoning and social impacts of mathematics, science and technology." This version of scientific literacy suggests that a conceptual learning approach is a pre-requisite for scientific literacy. The other multidimensional interpretations of scientific literacy focused on the skills and abilities required of someone who is technologically literate. For example, dealing with science related issues in society, and Fensham (1995) mentions this too. But, he adds a process of conceptual learning as a prerequisite for scientific literacy. This conceptual learning requirement also intimates that to be scientifically literate, one needs to have more than a simple vocabulary of scientific terms. Despite the process orientation of the definition provided by Fensham (1995), in a later publication (Fensham 1999) he concedes that the actual scientific literacy test administered by TIMMS in 1996 was largely (45 minutes) on the recall of science content. The rest of the time (15 minutes) was combined for questions on "reasoning and social utility in science and technology" (ibid:759).

The third interpretation of scientific literacy in the mid-1990s came from Bybee (1995). He described four dimensions of the concept scientific literacy in the true spirit of multidimensional scientific literacy. The four dimensions are functional literacy, conceptual and procedural literacy, and perspectives of science and technology. Bybee's (1995) interpretation of functional literacy differed from that described above as he confined the concept to scientific vocabulary while Miller (1983, cited in Shamos 1995) added the understanding of science processes, understanding of the impact of science and technology on society, and an active, intelligent involvement in public science policy debates. Conceptual and procedural literacy imply that "learners should relate information and experiences to conceptual ideas that unify the disciplines of science. In addition, literacy in science must also include abilities and understandings relative to the procedures and processes that make science a unique way of knowing" (Bybee 1995:29). The fourth dimension, perspectives of science, includes "the history of scientific ideas, the nature of science and technology, and the role of science and technology in personal life and society" (ibid). The four dimensions of Bybee's (1995) interpretation of scientific literacy manifest themselves in the National Science Education Standards (NSES) of America, described below.

In 1996, the National Academy of Sciences produced the NSES, which is part of the U.S. government's approach to reform education, an approach that involves setting national goals and the standards for meeting them" (DeBoer 1999:590).

According to the NSES,

> "*Scientific literacy means that a person can ask, find or determine answers to questions derived from curiosity about everyday experiences. It means that a person has the ability to describe, explain, and predict natural phenomena. Scientific literacy entails being able to read with understanding articles about science in the popular press and to engage in social*

conversation about the validity of the conclusions. Scientific literacy implies that a person can identify issues underlying national and local decisions and express positions that are scientifically and technologically informed. A literate citizen should be able to evaluate the quality of scientific information on the basis of its source and the methods used to generate it. Scientific literacy also implies the capacity to pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately"

(ibid:590-91).

The NSES definition of scientific literacy is very broad and includes all the goals of science education. As such it is could perhaps be described as too ambitious, but it does encompass all the elements of the concept scientific literacy. Once again, the multidimensional nature of scientific literacy is expressed in this highly evolved state of the concept. According to Laugksch (2000:79) "there is a high degree of congruence in the conceptualizations of scientific literacy between the National Research Council (National Academy of Sciences) responsible for the NSES and Project 2061" undertaken by the American Association for the Advancement of Science (AAAS). To avoid repetition, and because the NSES is more extensive (goes beyond standards for learners to standards for teaching, professional development, and assessment – see Laugksch 2000) than Project 2061, only the NSES interpretation of scientific literacy was discussed above.

Fensham (1999) offers another interpretation of scientific literacy developed by the Science Functional Expert Group (SFEG) of the PISA Project. According to the SFEG, scientific literacy entails "being able to combine science knowledge with the ability to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it by human activity" (ibid:761). This definition is a restatement of the application of scientific knowledge (like practical scientific literacy), and the impact of humans on the natural world. The definition is silent on the corollary of human impact on the natural world, i.e. the impact of the unnatural world, as in the case of depleted levels of ozone, on humans. Interestingly this is yet another instance where ecological impacts are brought to the fore in a definition of scientific literacy. Eisenhart, Finkel and Marion (1996, cited in Zuzovsky 1997:233) also mentioned quite explicitly that scientific literacy entails developing an "understanding the impact of decision on others, the environment and the future." More recently, Eilks (2000:16) insisted on the inclusion of "societal and ecological dimensions" in the teaching of chemistry. Fensham (1999) goes onto emphasize that the SFEG (1998) definition of scientific literacy is also a multidimensional construct similar to those discussed above. For example, the SFEG is bent on, amongst others, process skills, relevance of content to everyday situations, scientific investigation, and enduring relevance of concepts or content.

One of the latest additions to the advancement of scientific literacy is "the centrality of communications skills" (Hand et al 1999:1022). To this end, the importance of writing in science is a major focus in the works of Hand et al (2000) and Hanharan (1999). They argue that enhanced writing skills in science can lead to a variety of benefits like: representing scientific ideas better, keeping better records, solving problems, clarifying ideas, improved debate on science issues; and informed speculation about alternative scientific approaches. These researchers' works focus on the use of, for example, journal writing or group writing, and have yielded positive impacts on teaching and learning practices. The results though, cannot be generalized, because if "used by a teacher with a different philosophy and without genuine affirmation of the students' worth, it might not have the effect in that it had in this class, it might even cause harm" (Hanharan 1999:714). The relationship between writing skills and scientific literacy is important as described above, but the definition of the concept of scientific literacy has not yet been altered by research into writing skills. Nonetheless, as the relationship is receiving attention in the international research community, it was included in the discussion of the evolution of the concept of scientific literacy.

In conclusion to the exploration of the trajectory of the concept of scientific literacy, it is clear that the concept has evolved from a being a simple contribution to enhance the quality of general education in the 1930's to a sophisticated multidimensional concept in the 1990's. The multidimensional approach to scientific literacy embraces understanding of how science related actions impact the individuals who engage in them, understanding the impact of decisions on others, the environment and the future; understanding the relevant science content and methods; and understanding the advantages and limitations of scientific approach. Table 2.1. below attempts to summarize the chronological evolution of the term scientific literacy from the 1930s to date as described above.

Period or date	Person(s) responsible	Scientific Literacy ...
1930s	Dewey	was conceived as the unique contribution of science to general education.
1952	Conant	denoted a broad understanding of science.
1958	Hurd	was an understanding of science and its applications to social experience and science was integral to economic, political and personal issues.
1960s	Various	used as a major educational aim in the era of sloganeering.
1960s	Shamos	as knowing science in a humanistic way or feeling comfortable in reading or talking with others about science in a non-technical way.
1963	Hurd	is knowledge of key science concepts, relating these concepts in a coherent way, the social relevance of science, and the limitations of science.
1963	Koelsche	as the knowledge and skills required to read and understand science as presented in the media.
1966	Pella, O'Hearn and Gale	entailed interrelations between science and society; ethics of science; nature of science; conceptual knowledge; science and technology; and science in the humanities.
1971	NSTA	one who uses science concepts, process skills, and values in making everyday decisions as he interacts with other people and his environment, and understands the interrelationships between science, technology and other facets of society, including social and economic development.

1970s	Shen - Practical scientific literacy	included the kind of scientific and technical knowledge that can immediately be put to use to help to solve practical problems.
1970s	Shen – Civic Literacy	was a demand for knowledge that would enable citizens to become more aware of science-related issues, so that in a democratic society, they would have the power to affect public and technological policy.
1981	Branscomb	the ability to read, write, and understand systematized human knowledge.
1983	Arons	correctly apply scientific knowledge and reasoning skills to solving problems and making decisions in their personal, civic, and professional lives.
1987	Hirsch - cultural literacy	is a grasp of basic information needed to thrive in the modern world, something that was then translated into possession of a lexicon of scientific terms.
1989	Unknown - functional literacy	the level of understanding science and technology needed to function minimally as citizens and consumers in our society.
1980s	Project Synthesis	One who can utilize science for improving his/her own life and for coping with an increasingly technological world; One who can deal responsibly with science related society issues; One who can acquire the scientific and technological knowledge appropriate for his/her academic needs; and One who has an awareness of the nature of basic and scope of a wide variety of science and technology related careers open to students of varying aptitudes and interests.

1986	Scribner - ideal literacy	should be simultaneously adaptive, socially empowering and self enhancing.
1990	Hazen and Trefil	a scientifically literate person should be able to place the news of the day about science in a meaningful context…selected 18 general principles of science that cover a range of topics from absolute zero to X-rays.
1994	Baarah & Volk	requires a person to understand how science, technology and society influence one another, and is able to use this knowledge in everyday decision making.
1995	Shamos – true scientific literacy	entails that the individual actually knows something about the overall scientific enterprise. He or she is aware of some of the major conceptual theories that form the foundations of science, how they were arrived at, and why they are widely accepted, how science achieves order out of a random universe, and the role of the experiment in science.
mid-1990s	Netherlands Ministerial Advisory Committee	all citizens…(having) some idea of the origin, nature and impact of scientific knowledge…these citizens should also have insight into a scientists activities, e.g. designing and using models, developing theories, and carrying out experiments. Moreover, they should be aware of the important scientific and technological aspects of many political and social decisions in our society.
1995	Fensham	includes the residue of conceptual learning, contextualised in real world situations, and reasoning and social impacts of mathematics, science and technology.

1995	Bybee	the four dimensions are functional literacy, conceptual and procedural literacy, and perspectives of science and technology.
1996	Eisenhart, Finkel and Marion – Scientific Literacy is a Multidimensional construct	understanding of how science related actions impact the individuals who engage in them, understanding the impact of decision on others, the environment and the future; understanding the relevant science content and methods; and understanding the advantages and limitations of scientific approach.
1996	NSES	means that a person: can ask, find or determine answers to questions… has the ability to describe, explain, and predict natural phenomena..(can) read with understanding articles about science… can identify issues underlying national and local decisions…can evaluate the quality of scientific information…can pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately.
1998	SFEG	being able to combine science knowledge with the ability to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it by human activity.
1999	Jenkins	Citizen Science: science, which relates in reflexive ways to the concerns, interests, and activities of citizens as they go about their everyday business.

Table 2.1. The Evolution of Scientific Literacy from the 1930s to the 1990s

While there are many options to choose from Table 2.1, the interpretation that I am most comfortable with, relative to this study, is a combination of Shen's (1975, cited in Shamos 1995) practical literacy and civic literacy concepts. Therefore, the working definition of scientific literacy in this study entails having a knowledge that would enable citizens to become more aware of science-related issues so that the quality of their lives would improve by them applying scientific principles (practical literacy), and they would have the power to affect public and technological policy (civic literacy).

This working definition of scientific literacy is aligned to the scientific literacy test in this study for two principal reasons. First, by and large, the questions in the scientific literacy test attempt to transcend the assessment of scientific vocabulary (the so-called lexical knowledge of science). Some of the scientific literacy questions are aimed at increasing awareness of science-related issues, and the application of that knowledge in real life situations (practical literacy). For example, one question explores the influence of the force of inertia on a passenger travelling in a car when the car changes direction, and another question or focuses on the effect on the boiling point of the contents of a cooking vessel when salt is added. Yet another question deals with how pain experienced by the hand can be reduced when catching an object.

The second reason why this working definition is chosen for scientific literacy is that some of the scientific literacy questions in this study are designed to test whether students have the ability to affect public and technological policy (civic literacy). For example, the question on global warming tests if students know whether carbon dioxide gas is responsible for this phenomenon. Another question looks at the role of the layer of ozone in protecting the earth against the harmful ultraviolet rays of the sun, and the question on HIV/AIDS, tests if students understand all known methods of transmission of the virus. Thus, if students are in the know, they can respectively affect public and technological policy on reducing the emission of carbon dioxide gas, protecting of the ozone layer, and preventing the spread of HIV/AIDS.

The choice of a working definition of scientific literacy does not suggest that this definition is a universally acceptable definition. The concept of scientific literacy "has defied precise definition since it was introduced...many attempts have been made to define it, but none has yielded anything that approaches universal acceptance" (DeBoer 1999:582). In fact, scientific literacy is so broadly defined in the literature that it has "come to be an umbrella concept to signify comprehensiveness in the purposes of science teaching" (Roberts 1983, cited in Laugksch 2000:73). Therefore, the selection of a working definition then, is purely for the purposes of creating a theoretical basis to inform the scientific literacy questions in this study, as described above.

The foregoing analysis of scientific literacy provided a narrative and a tabular description of the evolution of the concept of scientific literacy and then distilled and justified a working definition of the concept of scientific literacy in the context of this study. The literature review now proceeds to explore the concept of technological literacy, to describe its evolution and then to distill a working definition in the context of this study.

2.3.4. Technological Literacy

Just as there is an assortment of conceptions of scientific literacy, so too are there a variety of understandings related to technological literacy. The different conceptions of technological literacy will be described below; however, it must be emphasized in advance that there is a dearth of literature available on the technological literacy. There are two main reasons for this limitation. First, more attention has been focused on the concept scientific literacy that spawned the concept of technological literacy. Technological literacy is a relatively new concept compared to scientific literacy. The origins of the concept scientific literacy were traced back to the 1930s and the concept of technological literacy was only alluded to in the 1970s when the concept of practical scientific literacy was presented by Shen (1975, cited in Shamos 1995) [see Table 2.1. pp.29-32]. Second, technological literacy is commonly subsumed within the scientific and technological literacy discourse. Regardless, of the limitations in the literature, every effort will be made to provide an insightful exposition of the different conceptions of technological literacy.

At the outset of this review on technological literacy, I want to problematize the notion of technological literacy and offer a personal perspective on the nature of the technological literacy that will be measured in this study. Waetjen (1993) contends that technology education does not have a structured body of knowledge, of organizing concepts, of underlying and fundamental principles, ideas that define an academic discipline. Therefore, it follows that there is no valid way of determining curriculum content. Hence, students cannot attain technological literacy if technology education has no structured domain of knowledge. Hook (2001:32) confirms the uncertainty associated with the nature of technology education when he states: "For years, most technology programs have wandered aimlessly, though with good intentions, through a maze of changes and choices with no road map to show the way."

I concur with the Waetjen (1993) interpretation that technology education lacks a structured domain of knowledge and therefore it is difficult to measure technological literacy as you would scientific literacy that has a defined curriculum content. Barnett (1995) contends that the lack of an agreed meaning for technological literacy reflects a widespread confusion about how the study of technology should be pursued. Todd (1991, cited in Waetjen 1993) says that we are unsure as to whether we are using technological literacy to represent a slogan, a concept, a goal or a program. What is surprising is that despite the confusion that reigns about technological literacy, there are publications in which sweeping statements are made about technological literacy levels without substantiation. For example, according to the Canadian Academy of Engineering (2000), there is a lack of technological literacy among the public and the technological literacy of many university graduates is open to question.

Based on the foregoing discussion on the lack of a structured domain of knowledge for technology and the confusion surrounding the concept, my theory is that this study does not measure technological literacy in the true sense. What is measured in this study is 'intuitive technological literacy' as the students did not take the subject at school level, and if they had exposure to technology education, it had no structured domain of knowledge. The concept of intuitive technological literacy is the author's contribution to the slew of terms that have been generated in developing an understanding of technological literacy.

According to the literature, it is the author's understanding that there are three distinct conceptions of technological literacy. The earliest conceptions of technology placed emphasis on conceptual material, e.g. understandings, knowledge, decision making, etc. Thereafter, there was an interim phase in the evolution of the concept of technological literacy that placed emphasis on tool skills, shaping materials and modeling. Subsequently, technological literacy evolved into a multidimensional concept, like scientific literacy did, to include, amongst others, applications of technology in new situations, the appreciation of values and societal issues, and the use of research skills to arrive at technological solutions.

With regard to the first conception of technological literacy that emphasized conceptual material, Waetjen (1993) concluded that technological literacy requires the ability of an individual to decode and encode technological messages. Encoding and decoding entail being able to understand and use words and their meanings. This emphasis on theoretical understanding was further demonstrated in Charp's (1996) incorporation of the concept technological literacy into the general concept of literacy. Charp (1996) believes that literacy includes the basic skills of reading, writing and arithmetic as well as computer and other technology related skills in the context of the workplace. Hayden (1989, cited in Waetjen 1993) furthers Charp's (1996) interpretation of the concept of technological literacy. He describes technological literacy as having knowledge and abilities to select and apply appropriate technologies in a given context. Perhaps this interpretation forms a bridge between the first conception of technology (emphasis on conceptual material) and the interim phase in the evolution of the concept of technological literacy (emphasis on skills).

The interim phase in the evolution of the concept of technological literacy placed emphasis on tool skills, shaping materials and modeling. This is a narrow conception of technological literacy because it includes computer skills and the ability to use computers and other technology. The interim conception of technological literacy still prevails in some contexts. For example, the former president of the United States described technological literacy as "computer skills and the ability to use computers and other technology to improve learning, productivity and performance..." (Clinton 1997:1).

President Clinton and Vice-President Gore of the United States introduced the Technological Literacy Challenge in 1996, which made the integration of technology into the classroom a national priority. To facilitate this priority, they set goals pertaining to the supply of training and support to all teachers, multimedia computers in all classrooms, connection to the Information Superhighway, and increased availability of effective software and on-line resources (Snyder 1997). The way in which technological literacy is perceived within the Technological Literacy Challenge of 1996 in the United States reinforces the interim definition of technological literacy which emphasized tools skills like computer skills and the ability to use computers and other technology. Bybee (2000) adds that the general lack of understanding of technology in society is confounded when we equate the theme of technology education with the use of computers.

In many instances, this interim phase in the evolution of the concept of technological literacy also listed conceptual knowledge together with tool skills as the requirement for technological literacy. For example, Croft (1991, cited in Waetjen 1993) proposed that a technologically literate person should possess basic literacy skills required to solve technology problems but also apply knowledge, tools and skills for the benefit of society; and ability to describe the basic technology systems of society. Also, Steffens (1986, cited in Waetjen 1993) claims that technological literacy involves knowledge and comprehension of technology and its uses, skills (tool and evaluation skills), and attitudes about new technologies and their application.

The interim conception of technological literacy as a combination of knowledge and skills did not remain static. Some authors like Fleming (1987, cited in Saskatchewan Education 2000) who subscribed to the multidimensional approach (particularly emphasizing societal influences) of technological literacy actually refined understandings of what constitutes knowledge and skills in technological literacy. Fleming (1987, cited in Saskatchewan Education 2000:1) claimed that:

> *in order to achieve an informed, balanced and comprehensive analysis of the technological influences on their lives and then be able to act on the basis of their analysis, students require certain levels of knowledge, skills and abilities. These included understanding that technology includes hardware, know-how, cultural needs and desires, and economic and political decision making; understanding how technology shapes and is shaped by society; understanding that technological issues involve conflicting assumptions, interpretations and options; having the necessary data collection and decision making skills to make intelligent choices; having the ability and desire to take responsible action on societal issues."*

Therefore, the knowledge and skills required of a technologically literate person had evolved from being confined to conceptual knowledge together with tool skills as conceived by Croft (1991, cited in Waetjen 1993) and Steffens (1986, cited in Waetjen 1993) above, to embrace knowledge pertaining to societal, economic and political decision-making as well as research skills.

The interim conception of technology inspired a multidimensional approach to conceiving technological literacy. Thomas and Knezek (1994, cited in Charp 1999) were emphatic that technological literacy transcended the ability to evaluate and use a variety of common technology applications as suggested in the interim phase in the evolution of the concept technological literacy. They emphasized that technological literacy also embraced the ability to innovate and invent ways of applying technology in challenging new situations; awareness of technology-related careers and of factors critical to success in those careers; and understanding and sensitivity to societal issues related to technology.

Some of the ideas from Thomas and Knezek (ibid) like applying technology in new situations and sensitivity to societal issues, resonate strongly with some of the critical outcomes for technology as envisaged in the Discussion Document of C2005 (DOE 1997a). For example, specific outcome one in the technology learning area of C2005 entails understanding and applying the technological process to solve problems and satisfy needs and wants; and specific outcome two embraces sensitivity to problems, dilemmas, issues and choices in society.

Fleming (1987, cited in Saskatchewan Education 2000) refined the societal approach to technological literacy. He described technological literacy "as the intellectual processes, abilities and dispositions needed by individuals to understand the link between technology, themselves and society in general" (Saskatchewan Education 2000:1). This societal focus provided by Fleming (1987, cited in Saskatchewan Education 2000) resonates with the White Paper on Science and Technology (DACST 1997:4) which insists that a society "must ensure that its members develop and continually update the knowledge, competencies, abilities and skills that are required to produce innovative products and services." Both Fleming (1987, cited in Saskatchewan Education 2000) and the White Paper on Science and Technology (DACST 1997) endorse the idea that technological literacy is about developing awareness of how technology is related to the broader social system, and the political, cultural and economic frameworks which shape it. The capacity to make critical judgments involving technology increases the ability of citizens to use such knowledge to shape and influence their environment.

Another important contribution provided by Fleming (1987, cited in Saskatchewan Education 2000) to the development of an understanding of the concept technological literacy pertained to values. He stated that values also influence intellectual processes, since anything that involves choice also involves consideration of whose values are shaping a particular technological development. There is a similarity here between the development of the concepts of technology and technological literacy. Naughton (1990) believed that technology can be informed by other kinds of knowledge like experience, craft knowledge and feelings about a particular product, so too does Fleming (1987, cited in Saskatchewan Education 2000) believe that technological literacy involve values.

This concept of values and its influence on technological decision is interesting. On the one hand, Fleming believes that there is a subjective bias in the technological choices that we make. On the other hand, a later interpretation of technological literacy (Dugger 2000) encourages objectivity if one is technologically literate. Specifically, Dugger (2000:10) states that a technologically literate "is comfortable with and objective about technology..." Quite frankly, I concur with Fleming, as it is impossible to ignore values when technological choices are being made.

The foregoing discussion on technological literacy has shown the developments of the concept of technological literacy. First, there was an emphasis on conceptual material, then an emphasis on technological skills; and finally a multidimensional concept emerged. The latter included applications of technology in new situations, an appreciation of societal issues and values, and the use of research skills to arrive at technological solutions.

For the purposes of this study, a technologically literate person is someone who critically "analyzes the pros and cons of any technological development (using reliable research methods), to examine its potential benefits (and demerits), its potential costs, and to perceive the underlying political and social forces (especially values) driving the development" (Fleming 1987, cited in Saskatchewan Education 2000:1).

The above interpretation of technological literacy is the second working definition derived in this chapter, the first working definition pertained to scientific literacy. The technological literacy working definition strikes a chord with this study because it is aligned to the test for technological literacy in three specific ways.

First, the working definition speaks of the analysis of pros and cons of a technological development to examine its potential benefits and demerits, and its potential costs. This is the very nature of two of the questions in the technological literacy test which relate to the factors that are taken into consideration when purchasing a cell phone, and the impact of the Internet on society. The question on the cell phone, in accordance with specific outcome four in the technology learning area as outlined in the Discussion Document of C2005 (DOE 1997a), explores whether students are able to select and evaluate systems. This question allows students to analyze the pros and cons of different types of cell phones that are available on the market by reviewing their characteristics, functions and costs. Similarly, the question on the Internet tests whether students understand the impact of technology. In this question, students can examine electronic communication and quick access to information, and their impact on society, the economy and the natural environment.

Second, the underlying political ramifications of technological literacy alluded to in the working definition above are tested when the students are requested to comment on whether the drug AZT should be made available in South Africa. The South African government is clearly opposed to making the drug AZT, and its successor Nevirapine, available in public hospitals. Specific outcome seven in the Discussion Document of C2005 (DOE 1997a) encourages students to understand how technology might reflect different biases. Moreover, students need to understand how access to technology has been denied in some cases.

Third, the impact of social forces, mentioned in the working definition of technological literacy, cannot be underestimated. The technological literacy question pertaining to the resolution of sanitation problems at an informal settlement brings this point to the fore. This particular question also has a research method built into its different components, which is yet another feature of the working definition of technological literacy. In solving the sanitation problem, the students need to understand what the community envisages as a solution to the problem. The students cannot simply proceed with a solution blind of the solutions offered by the residents of the informal settlement as the intervention will never be sustained if the locals do not own it.

The two concepts of scientific and technological literacy will now be problematized further in attempting to answer the more controversial question of whether scientific and technological literacy are necessary.

2.4. Is Scientific and Technological Literacy Necessary?

There are both optimistic and pessimistic responses to this question of whether scientific and technological literacy is necessary. The optimistic responses offer empowerment of the people and economic prosperity for South Africa. The pessimistic responses tend to be peppered with cynicism but they are also convincing. I will first elaborate the optimistic and then the pessimistic responses from the literature.

Some of the optimists include Stahl (1994), Doke (1998) and Dugger (2000). Stahl (1994:44) maintains that "scientific and technological literacy enables the general public to understand events and ideas related to scientific discovery and technological development, and thereby to exercise the rights and responsibilities of citizenship in a democratic society." These views are similar to those of Fleming (1987, cited in Saskatchewan Education 2000) discussed above. Stahl (1994) goes on to impress upon us that scientific literacy will help to distinguish fact from misinformation, and to be aware of political and cultural biases when policy decisions are taken.

Doke (1998) impresses upon us that science and technology are the keys that will unlock a prosperous future for South Africa. "South Africa needs to nurture science and technology for its children to leap forward armed with knowledge into the next millennium...People with scientific insight gain power over their environment. Scientific enquiry forms a core competency that supports technological enterprise. If that core competency is lost within a nation, that nation becomes powerless against its competitors" Doke (1998:1). South Africa needs to capitalize on its scientific and technological wealth to advance technologically and economically as a nation.

Dugger (2000) contends that technological literacy enables people to develop knowledge and abilities about human innovation and action. There are elements of the thinking of Stahl (1994), Doke (1998), and Fleming (1987, cited in Saskatchewan Education 2000) in Dugger's (2000) views. Dugger (2000) reiterates the importance of a technologically informed citizenry to be involved in decision-making processes, as endorsed by Stahl (1994) and Fleming (1987, cited in Saskatchewan Education 2000). He then echoes the economic outcomes of a technologically literate society as Doke (1998) did, "in (helping the) nation maintain and sustain economic progress" (Dugger 2000:10).

Bauer (1992) was one of the principal pessimists on the necessity for scientific and technological literacy. Bauer (1992) provides a list of reasons as to why scientific literacy is necessary but then goes on to contest each of these reasons:

First, it is apparent that knowing science enables people as voters and as consumers to make better decisions. Bauer (1992) believes that this is not necessarily true, as even brilliant scientists have, on occasion, not been able to arrive at correct decisions. Stahl (1994) offers an interesting rebuttal to this undesirable reality. He asserts that people who are scientifically literate have a general comprehension of principles rather than an encyclopedic knowledge of facts. Therefore, even scientists can arrive at wrong decisions when they are out of their depth. However, that is not a good reason not to pursue specialist interest in a particular field.

Second, supposedly understanding modern technology brings economic good and thereby aids national security. This claim is supported by the assertion that science spawns technology. However, even though the quality of science has been unexcelled in the United States in the past half-century, it is Japan that has excelled technologically. The relationship between science and technology is anything but straightforward. That Japan has excelled technologically cannot be disputed but surely there are other factors beyond just technological acumen that result in economic prosperity. Amongst other attributes, the Japanese are diligent and industrious people and economic success also hinges on these factors.

Third, allegedly scientific knowledge supplants superstition. This is not necessarily true in that many scientists still cling to superstitious views despite their scientific knowledge. Indeed, people, be they scientists or not, are influenced by a variety of factors like personal belief systems and misconceptions. Thus, this eventuality of clinging to personal beliefs can prevail.

Fourth, maybe if we learn to think scientifically, that is, in terms of predictable consequences of actions, then our actions will become more rational. But scientists do not exhibit a higher level decision-making or behaviour than others. As mentioned above, beyond their fields of expertise, scientists flounder as any normal person would when making decisions. Yes, scientists and normal citizens do cling to certain principles of science but these do not reign exclusively when decisions are made.

Fifth, perhaps familiarity with the scientific method will lead to a more ethical attitude. But, behaviour is not directly governed by intellect. This can also hold true particularly because we all have values and biases that influence the decisions that we take. The issue of values was discussed above relative to technological literacy and it was concluded that values also influence intellectual processes since anything that involves choice also involves consideration of whose values are shaping a particular technological development.

Indeed, it is difficult to dismiss the cynical, yet convincing, arguments presented by Bauer (1992) as to why scientific literacy is not necessary. In contrast, Stahl (1994) is convinced that critical citizenry will be a natural outcome of scientific literacy, and Doke (1998) impresses the economic empowerment associated with scientific and technological literacy. However, the realities presented by Bauer of scientists not being able to arrive at correct decisions or other factors beyond just technological acumen that result in economic prosperity, do generate a sense of doubt as to whether scientific and technological literacy is necessary. Moreover, the influence of personal belief systems values, biases, and misconceptions on decision-making processes cannot be ignored (Bauer 1992).

But to acquiesce to Bauer (1992) would be tantamount to surrendering all hope of scientific, technological and economic advancement. Rather, one should acknowledge the challenges outlined by Bauer (1992) and take them into consideration when aspiring towards scientific and technological literacy for all, not scientists exclusively. In any event, most of the criticisms offered by Bauer (1992) pertain to the limitations of scientists, and according to Cross and Price (1999) the apparent dependence on scientists to arrive at correct decisions provides all the more reason to pursue scientific literacy for all, not scientists exclusively. They go on to impress that the reliance on experts has led to the rise of "expertocracy with its accompanying interests, both political and economic, (and that)... is a threat to democracy" (ibid:783).

2.5. <u>Conclusion</u>

This chapter analyzed and traced the evolution of the assortment of conceptions of scientific and technological literacy. The root concepts of science and technology were examined to explain the combined use of the terms as if they were one entity, and to develop clear definitions of the terms. Science and technology were eventually distinguished on the basis of their purposes, scientific activity is to build up knowledge and technological activity is to put knowledge to good use by solving some practical problem. Thereafter, a wide range of perspectives on the two concepts of scientific and technological literacy was presented. The concept of scientific literacy evolved from a being a simple contribution to enhance the quality of general education in the 1930s to a sophisticated multidimensional concept in the 1990s which embraced, amongst others, an understanding of how science related actions impact the individuals who engage in them. The concept of technological literacy evolved from a concept that emphasized conceptual material; to an emphasis on technological skills; and finally into a multidimensional concept, to include applications of technology in new situations, an appreciation of societal issues and values, and the use of research skills to arrive at technological solutions. Operational definitions for scientific and technological literacy were also provided to inform this study. Finally the discussion moved on to the necessity for scientific and technological literacy. In this concluding component, the optimistic and pessimistic viewpoints were presented, and it was resolved that to acquiesce to the pessimist Bauer (1992) would be tantamount to surrendering all hope of scientific, technological and economic advancement. Rather, one should acknowledge the challenges outlined by Bauer (1992) and take them into consideration when aspiring towards scientific and technological literacy for all, not scientists exclusively.