Volume 5 Number 2 July 1993 ISSN 1013-3445

CONTENTS

Nature of Science (NOS) in Science Education: Possibilities and Constraints in a Developing Country, Zimbabwe[1]

Overson Shumba
Department of Teacher Education
University of Zimbabwe

Abstract:

This paper examines contemporary thinking and understanding of the nature of science and science learning and attempts to show how this understanding can help African systems achieve their modern science and technology (S & T) education goals. A brief survey of " traditional" western science is given as a prelude to a discussion of current notions on the nature of science particularly aspects related to the relationship between observation and theory, methods of science and school practical work. In addition to identifying common distortions on the nature of science, many factors that typically influence the quality of science education are discussed particularly in relation to professionally empowering the African science teacher.

Introduction

It would seem that globally science education is generally viewed as being in a state of crisis (Gardner and Yager, 1983). The literature in which the term "crisis" appears suggests that this condition has persisted throughout the 1980s and does appear quite endemic in the early part of the 1990s

---

1 *The author acknowledges the suggestions of Professor Lynn W. Glass at Iowa State University of Science and Technology in reviewing earlier drafts of this article.*

(Cleminson, 1990; Duschl and Gitomer, 1991; Hodson, 1988; Burbules and Linn, 1991). Everywhere, a major aspect of the current crisis revolves around how best to prepare students for further education and careers in science, and at the same time provide for the majority of students who will not in the future pursue science academically or professionally. The "crisis" condition has been characterised chiefly with reference to the science curriculum failing to demonstrate the impact of both S & T on society and on its ceaseless perpetration of the distorted image of science (Harms and Yager, 1981; Duschl, 1988; Wagner, 1983; Tamir, 1983; Cleminson, 1990; Duschl and Gitomer, 1991; Hodson, 1988; Burbules and Linn, 1991). Unlike in the past when pre-college programmes were the explicit target for innovation, science teacher preparation is increasingly receiving attention (Glass and Aiuto, 1992).

In the past three decades, reform in science education has come out, firstly, with various statements of outcomes and goals that should constitute the purpose of pre-college science. It is now generally accepted, both in developed and less developed countries, that the role of science education is in preparing individuals to utilize science of improving their own lives and to cope with an increasingly technological world. Science should prepare individuals who are informed to deal responsibly with science related societal issues and at the same time give all students an awareness of the nature and scope of S & T related careers open to students of varying aptitudes. It must assist individuals to acquire the academic knowledge they may need to pursue the study of science academically as well as professionally along the lines described in and popularised by the National Science Teachers' Association's *Project Synthesis* (Harms and Yager, 1981; Chisman, 1984; UNESCO, 1983). In what reflects, implicitly, these same goals the Zimbabwe Ministry of Education and Culture (MEC) (1992) has reformed its science curriculum by defining relatively similar goals. In a study of science teachers in Harare Region (Zimbabwe), it was found that teachers perceived these goals positively as reflected in their syllabus and as emphasized in their science teaching (Shumba,1992a)

Secondly, reform also has seriously addressed issues related to science programmes suitable for those students unlikely to pursue science at an advanced level either academically or professionally with the intents of making them scientifically and technologically literate so that as citizens they can vote, take sides and decide on issues with a scientific and technological input in an informed and knowledgeable capacity (Burbules and Linn, 1991). Whilst there is a clear vision of what should be the outcomes in science education, the accomplishment of the outcomes is a still to a large extent wishful thinking. For example, sufficient evidence exists to suggest that teachers and the curriculum which articulate and purport to develop scientific and technological literacy are both continuing to present a distorted image on the nature of science (NOS) (Harms and Yager, 1981; Duschl, 1988; Wagner, 1983; Tamir, 1983; Cleminson, 1990; Duschl and Gitomer, 1991; Hodson, 1988; Burbules and Linn, 1991). Some educators strongly believe that understanding the proper NOS is the sin qua non of scientific and technological literacy (STL), and that the reason the "crisis" in education seems unabatable and self-perpetuating is because the science curriculum lacks inputs from the history and philosophy of science (HPS), and from cognitive science (Duschl, 1985 and 1988; Wagner, 1983; Cleminson, 1990; Duschl and Gitomer, 1991; Hodson, 1988; Burbules and Linn, 1991; Mathews, 1990) In this respect the mutual exclusivity idea (Duschl, 1985) which propounds that science education promotes notions at variance with contemporary ideas in philosophy, history and sociology of science is still a valid conjecture.

An increasing number of science educators, thus, now advance the role and contributions HPS can play in order to make the curriculum valid, authentic, and successful in developing STL. For Gardner and Yager (1983) the problem with past curricula, and to a relatively large extent current curricula, was that too few educators were ready and able to view the situation at a philosophical level. While in the early part of the last decade identifying the objectives of scientific practice remained a "challenge for anyone with a serious commitment to science education" (Wagner, 1983; p605), we find ourselves in the 1990s with ideal and altruistic goals and outcomes but whose implementation and attainment appears neither systematic, predictable nor foreseeable. It would seem appropriate to conjecture that in order to attain modern goals of science education, it will be necessary for science educators at all levels to have a clear understanding of the NOS and how children learn science (Burbules and Linn, 1991; Loving, 1991; Tamir, 1983; Hodson, 1988; Duschl and

Gitomer, 1990; Cleminson, 1990). Mathews (1990,45) notes that "a discussion of critical thinking independently of scientific thinking is greatly truncated" and thus underscores the significance for science educators to clearly understand scientific thinking and the NOS as enlightened by contemporary thinking in the HPS.

In this paper, it is proposed that understanding of these aspects is probably even more fundamental in African systems which are usually the recipients or importers of diverse forms of S & T. Numerous reasons can be advanced for this conjecture. First, curricula in many African systems are often adoptions or close adaptations of western forms (Chisman, 1984; UNESCO, 1983; Ogunniyi, 1986; Nichter, 1984). Second, for the African student, there is always inherent conflict between the learner's traditional view of the world and that advanced in science courses (Ogunniyi, 1988) Ogunniyi in Nigeria found that the scientific view may not easily displace the African traditional view but that the traditional view might be enlarged by exposure to a well organised history/philosophy of science course. Third, increasingly the scientific world is commonly interchanged with "modernism" (UNESCO,1983; Ogunniyi, 1988) to the extent that

> countries anxious to modernize their economies by adopting scientific methods, science is increasingly seen as a social institution which must be part of life. (UNESCO, 1983)

Zimbabwe's latest Five Year National Development Plan (1991-1995) acknowledges the centrality of S & T in economic and social transformation.

Fourth, Africa is part of a global economy and thus Africa's educational systems need to and must increase their potential to participate and contribute. Miller (1984) makes the observation that S & T have become a significant part of modern culture to the extent that

> even when science is not well understood, or even when it is only manifested in technology which is used in our work or play, the effects are still significant.

Fifth, many African systems seeking to improve their productivity and their economies have paid little attention to the distinction between S & T to the extent that the two constructs have paired to "such an extent as to imply some insoluble bond between them" (UNESCO, 1983). This has implications in selecting, adapting or adopting what many African systems have termed 'relevant' and 'appropriate technology', typically expected to be dependent upon understanding of various technologies, and the level and strength of critical analysis and decision making.

This paper examines contemporary thinking and understanding of the NOS and science learning. A brief survey of "traditional" science is presented as a prelude to a discussion of NOS, role of HPS in science teacher training, and factors and constraints that qualitatively influence both the pace and effectiveness of S & T education progress with reference mainly to the Zimbabwe context.

Traditional western science education and its shortcomings.

Traditional science is taken as practised in science curricula that do not take into account current thinking in the HPS and/or the constructivist approach to science learning (Tehart, 1988; Hodson, 1985; Duschl, 1985 and 1988, Hodson, 1988; Duschl and Gitomer, 1991; Cleminson, 1991; Loving, 1991). Tehart (1988) observes that traditional science is based on some "standard philosophy of science" consisting of "scientists compiling truths,... scientific research as cumulative and science teachers passing these cumulated truths to the next generation" and hence is characterised by a distorted image of the NOS. The new science education is based on the "new philosophy of science" in which

> an historically informed concept of scientific development is regarded as a necessary condition for a practice of school science teaching leading to knowledge and understanding. (Tehart, 1988, 11).

In the 1960's when traditional science in the context of this discussion began in the USA , it was perceived essential to teach fundamental and rigorous science with the intention of raising technological levels above those of the USSR and thus science education reform at this time had a technocratic outlook that asserted military, political and technological supremacy. While it stressed a rigorous science, it failed to focus attention to the social roles and impact of science and their relevance to students who quit the pursuit and study of science at school level. The notable result of this technological competitiveness has been tremendous acceleration in the rate at which scientific and technological know-how has become part of everyday living but with its attendant social problems and consequences. These antecedent developments served as a precursor to two problems whose solutions have become the prerogative for individuals, communities, nations and the world. At the fore is the quest for understanding and solving 'S & T related' problems, coping with S & T driven societies, and boosting economic development and competitiveness in a global economy (Hurd, 1990; Burbules and Linn, 1991). Second, prevailing assumptions of earlier curricula resulted in a distorted image of science and the nature of scientific inquiry (Hodson, 1988 and 1990; Mathews, 1990). For solving both problems, attention is increasingly being paid to the messages on NOS in science curricula.

Distortion in African systems could be magnified compared to western systems where science can be considered to have become part of culture (Hurd, 1990). Attitudes at pre-independence meant that the curriculum was perceived as foreign, contextually-barren, and largely irrelevant to the experiences of both teachers and students. In any case, science as understood in western cultures has to compete with indigenous knowledge systems of viewing the world and of explaining phenomena. When attitudes are negative, distortions are inevitable. At post-independence, equitable access to science education meant massive expansion in size of classes in comparison to the relatively stable financial and material resources pools. Teacher shortage, large classes, and lack of resources, particularly deficiencies in technology, work additively in ways predicted to result in distortion of scientific activity, at least at the school level. Further,(Ogunniyi,1986 ,118) observes of African systems:

> An important item that is missing in the development of science education in Africa has been the conspicuous absence of an active involvement of the scientific community.

Traditionally, curricula assumed that scientific knowledge and outcomes of science were best learned through procedures of science and hence the apparent congruence between pedagogic content of learning experiences and the syntactic structure of the subject matter being mistakenly accepted as real (Hodson, 1988; Mathews, 1990). The methodology of science was viewed from the inductive stand-point as starting from simple unprejudiced observations leading to generalizations on which basic predictions could be made. Originating from inductive and posivist thinking was the belief in a single, stable and generalized scientific method that could be characterized by a series of sequential steps (Edmund, 1992). "The Scientific Method", it was believed, could be taught "independent" of content with processes preceding concepts and that these processes could transfer to new situations. According to this view, theories and models were assumed to remain the same and unchanging over time (Hodson, 1988 and 1990). Many like Hodson assert that the link between theories and observation were rather simplistic (Tehart, 1988; Mathews, 1999; Cleminson, 1990; Burbules and Linn, 1991). A disturbing observation was that school experiments were erroneously presented as paralles of scientific research and as testing theories (Hodson, 1988).

On the pedagogical front, the following distorted views prevailed. Teaching processes of science was viewed as both teaching *as* inquiry and *by* inquiry (Tamir, 1983; Hodson, 1988). Teaching of science as inquiry refers to a curriculum emphasis on the process of science while teaching of science by inquiry refers to using the process of science to teaching and learning science. Both were not significantly evident in science classrooms. Geddis (1988) suggests that the typical classroom had a hierarchical structure dominated and controlled by the teacher. The transmission model of instruction is counterproductive as Young (1980) (cited in Geddis, 1988, 4) observed.

> The teacher, primarily in reformulating, does the work of generalization, specification, increasing precision, testing hypotheses and the like. In cryptic, short replies pupils offer largely recitation of information already defined by the teacher or textbook and supplied to them. Topic choice, concept formation, theory choice, and theory tests are all out of the pupils' hands.

In doing this, teachers replace student discourse and systematically exercise complete monopoly on higher order intellectual acts (Geddis, 1988). The generally practised methodologies of teaching were almost purely inductive in which teaching methodology was largely derived on the basis of the subject matter structure. Unfortunately, this pattern of teaching is the most evident in many education systems including Zimbabwe (Haeck, 1990; Hodzi, 1989, Shumba, 1991 and 1992a). In Zimbabwe like in many countries, regrettably, the teacher is least likely to get in-service support or assistance for innovative teaching from within the school, either from the school head or from the other science teachers (Nyagura and Reece ,1989; Shumba, 1991b and 1992a).

A final assumption was that discovery learning methods would directly lead to students conceptual change and development. While discovery learning methods combined use of science processes to teach and learn science and progressive child-cantered views that emphasize direct experience and individual inquiry, they were based on false and absurd logic (Harris and Taylor, 1983 in Hodson, 1988). Hodson explains:

> Discovery methods can legitimately investigate the relationship between concepts but they cannot, with certainty, lead to the formation of new concepts and new conceptual structures. The acquisition of new knowledge depends, in part, on the structure and organisation of that knowledge and, in greater part, on the learner's existing knowledge.

While scientific investigation depends on and requires multiple sources of information, much of the scientific information which students received was contained in singular sources, textbooks. According to Mayer (1983) texts influence the way students perceive the scientific enterprise. Unfortunately the emphasis in commercial textbooks as reflected in content analysis studies is on facts, terminology and vocabulary and on presenting science as a body of information (Yager, 1983). Although ideas are mentioned, texts fail to develop these ideas and concepts around "the models that scientists used to form these concepts" (Chiapetta, Sethna and Fillman, 1991, 940), thus reflecting a superficial and parsimonious treatment of both subject matter and NOS. Chiapetta and colleagues assert that texts should present science as a humane enterprise stressing knowledge, investigation, thinking, history of science, technology, and should reflect upon the impact of S & T on society in addition to presenting an authentic and accurate view of the content and methods of science or NOS.

It is important to note that in the developed world the inadequacy and shortcomings of texts is judged on the basis of many and diverse texts yet in African systems texts are a scarce resource (Ogunniyi, 1986)and therefore because of this scarcity, teachers and in turn their students fail to benefit from diversity of perspectives, experiences, philosophical orientations and epistemological leanings of text authors or publishers. It is conjectured that distortion of the NOS due to a lack of multiple-view-points is most likely to be prevalent.

Authenticating the Nature of Science (NOS) and Scientific Knowledge

It is evident that traditional post-Sputnik science curricula originating in either the U.K. or the U.S.A. had severe limitations and assumptions yet science curricula from groups in these countries are widely adopted or adapted globally. The author was able to identify ten common distortions of the NOS. In this section, each distortion is stated followed by a brief elaboration of the new postulates on the NOS. Detailed discussions occur in the original sources from which they have been synthesized (Cleminson, 1990; Duschl and Gitomer (1991); Loving,1991; Hawkins and Pea, 1987; Reif and Larkin, 1991; Mathews, 1990; Tamir, 1983; and others referred to throughout the paper). The order in which the ten distortions are presented or enumerated in the paper have no practical or theoretical significance.

The first distortion is the view that scientists are passive, impartial, unbiased and objective observers of the world. This has been rejected on the grounds that it represents the notion that observation is a theory free process not influenced by prior knowledge and thus is an inhuman process (Cleminson, 1990; Duschl and Gitomer (1991); Loving, 1991). It is now accepted that observations are theory laden being influenced by knowledge, beliefs and theories which determine our perceptions (Cleminson, 1990; Loving, 1991). The observer (the scientist) and the observed are part of one system and therefore scientists cannot be disinterested observers. Accordingly, value free investigation is not feasible and hence the notion of scientists as participants shaping, not only documenting, their objects of study is considered more tenable (e.g. Hawkins and Pea, 1987, 29). Duschl and Gitomer, (1991) illustrate this point with reference to Laudan's (1984) reticulate model. In that model of scientific progress, it is asserted that the aims of the investigation justify methodology and that the methodology selected must harmonize with theory or current knowledge. In turn the methodology justifies theory; and theory constrains methodology and harmonizes with aims. Aims of investigations are thus shaped by both existing theory and existing methodology.

A second distortion was the view that scientific progress is a smooth cumulative process involving making deductive generalizations on the systems observed. It is now generally held that scientific progress is a 'revisionary process' rather than a simple cumulative process. Scientific knowledge is seen as crucial interpretation of phenomena not merely deductive generalizations from the 'facts' of observation (Hawkins and Pea, 1987). The generation of scientific knowledge can be accomplished in a variety of ways including logical argument and deduction which do not necessarily begin from experimentation (Mathew, 1990; Duschl, 1990; Hodson, 1985). The serially ordered events of inductivism leading to 'the scientific method' are no longer tenable.

Linked to the first distortion of the NOS is a third which asserts that scientific knowledge is public, objective and unbiased knowledge without a social context. While acknowledging that scientific knowledge is public, this view failed to realize the sociological context of scientific endeavour. Science is now understood to be socially constructed knowledge in which the personalities of those involved have impact on the pace of scientific advance as well as on the selection of a research agenda (Songer and Linn, 1991). As a social activity, science is disseminated for public and peer scrutiny through journals, conference proceedings, and other fora at which this knowledge is checked and evaluated against both past and existing forms of knowledge. This process underscores the importance of the historical context of science in which the longitudinal development and growth in scientific knowledge is embedded and from which it can be traced (Mathews, 1990; Duschl, 1990; Hodson, 1985).

Despite the rapid advance in S & T and concomitantly our understanding, the scope of science is construed as unlimited and consisting of a stable body of knowledge (facts, concepts, and principles). Philosophers in science today generally consider that theory, no matter how dominant, can be challenged and that 'fact' is no longer an objective statement (Cleminson, 1990). Duschl (1988) describes and rejects this assumption as representing the 'scientistic' legacy of science education of the past in which "the scope of scientific authority is unlimited and beyond reproach" (p. 52). As with arguments disapproving the second distortion, scientific progress is seen as an evolutionary process in which current views and theories are altered to take into account more plausible and compelling postulates.

The fifth distortion is based on UNESCO's (1983, 17) observation that science and technology are often treated simultaneously as similar and inseparable. UNESCO asserts that the terms 'science' and 'technology' tend to be mistakenly paired to 'such an extent as to imply some indissoluble bond between them' . While scientific activity purports to construct knowledge and to give an explanation for something, technological activity purports to facilitate human aspiration by putting knowledge to use in solving some practical problem. In pursuit of these goals "both science and technology employ existing knowledge and existing know how. Both dip, as it were, in each other's basket. In this sense they are *interdependent*" (emphasis added). The NOS is relatively incomplete if little attention is paid to the distinction and understanding of the interdependence of S & T, and their impact on society.

Distortion six originates from the long standing and prevalent assumption of the "scientific methods" which can be characterized as a sequence of steps that can be taught. Cleminson (1990, 437)) describes and rejects the notion of the 'scientific method' as "an ephemeral and incomplete description of scientific activity" . More recently, Norman Edmund (1992) describes 'the scientific method' as the 'banished', the 'non-logical' thing 'only for scientists'. According to several postulates, science consists of a range and variety of methods which change and develop depending upon the nature of the problems to be investigated, the current knowledge in the science community, and the range of techniques, instruments and methods available as illustrated by Laudan's model (Duschl and Gitomer, 1991) and Hodson's (1988) dynamic model. Both models articulate the dynamic relationship between scientific method (process) and scientific knowledge or theory (product) in which the existing knowledge informs and determines the processes by which further knowledge is generated and validated (Hodson, 1988,24).

Edmund (1992, 7) posits a general pattern of the scientific method:

> The general pattern of the scientific methods is not just a method for scientists. It is really a general method suitable for all types of problems and decisions in business, publishing, industry, and all other domains, including one's personal life and involving not a series of sequential steps but a lot of skipping, stalling, backtracking, looping, coiling, and concurrent use of ingredients.

The basic ingredients are conceived to represent the generic scientific process of finding out such as originating a problem; stating goals and planning; gathering evidence; generating creative and logical alternative solutions; and evaluating the evidence.

While the second distortion suggested scientific progress as a cumulative process, distortion seven is a presentation of theories as statements of generalization derived from repeated observation of phenomena. Theories are currently viewed as useful for explaining experiences. They progress through qualitative developmental stages to more precise and complex forms not necessarily based on observational data (Duschl and Gitomer, 1990). Scientific explanations are multiple and styles of explanation change. It is theoretical concepts which give experience meaning, and not observational experience giving meaning to concepts. The curricula of yesteryear were thus based on the incorrect assumption that processes of science precede concepts (Hodson, 1988).

The last three distortions are strongly related to and influence pedagogical approaches to science teaching and learning. The first distortion among these, distortion eight, assumes that teaching science as inquiry is synonymous with teaching science by inquiry. Both Tamir (1983) and Hodson (1988) describe teaching science as inquiry as what is taught and learned (instructional products or outcomes), and teaching science by inquiry as how instruction is executed (institutional process). According to both Tamir and Hodson, teaching science as inquiry does not necessarily require use of practical work. Tamir(1983,660) states that:

> one can teach science as inquiry by presenting a lecture using a narrative of inquiry, and that one may not teach science as inquiry by putting students through laboratory exercises which are merely aimed at finding the right answer by following a set of steps.

Teaching science as inquiry and teaching science by inquiry are elaborately distinct constructs both desirable in science education. Typically, teaching science by inquiry is associated with hands-on-activity-oriented investigations in which students are actively involved in constructing concepts.

Partially, a consequence of the eighth distortion is distortion nine where school laboratory work is mistakenly viewed to represent and to replicate what scientists do including testing theory (Hodson,1988). School practical work is simply not theory testing and neither does it correspond directly to the experimental phase of scientific research! Hodson observes that much laboratory work is unproductive because teachers are not always clear about its purpose and because they attempt to use a singular experience to achieve multiple goals or purposes. Practical work in science is not synonymous with laboratory experiments but should "comprise a variety of active learning experiences" regardless of whether the work is conducted in the classroom or in the field. Hodson (1988, 35) asserts that

> learning about the nature of experimentation in science is one of the goals of science education and, paradoxically, is

one that is not necessarily best approached via laboratory work .

Examples for which experiences different from the typical laboratory experiments may include: critical scrutiny of evidence and arguments for and against particular theories; practice in using theories for explaining phenomena; testing hypotheses by logical criticism, e.g. for internal consistency and compatibility with existing theory; and appreciation of socio-economic and historical issues concerning science and its applications. It can also be approached through case studies focused both on theoretical and social circumstances of discovery and on biographical accounts serving to underscore the importance of social and human nature of scientific activity and knowledge generation (Hodson, 1988). Highlights in the case study approach would include personal beliefs and attitudes of the scientist(s) at the time, nature and significance of problems as they appeared at the time, community and societal reactions and pressures at the time, and perhaps relevance to our current understanding of problems and knowledge in the area aspects often missed in science classes.

Distortion ten presumes that the nature of scientific activity is distinct from the nature of learning science. Duschl and Gitomer (1991), and Cleminson (1990) postulate that there is a common epistemological base between the tentative NOS and the generative model of learning science. Contemporary arguments in the philosophy of science articulate that the focal point of all scientific activity is to generate knowledge (or theory) a process that involves constructing meaning in attempt to understand the world (Duschl, 1990; Hodson, 1985; Mathews, 1990). Scientific knowledge or theory is perceived as tentative and amenable to revision, alteration or replacement. According to this developmental model, change in the status of scientific theory is possible because the community of scientists continually and critically reflect upon their understanding. It has been proposed that science is a reflective process necessitating the inclusion of meta-cognitive processes such as reflective thinking as outcomes of science instruction and assessment (Paulson and Paulson, 1991).

As with the postulate of scientific progress above, psychologists such as Driver (1981) and Carey (1986) have enunciated that children learn science best through active hands-on activity in which individuals are actively involved in constructing, revising, altering, and replacing concepts. Cleminson (1990 ,441) makes this point further when he states that learning science is a very personal activity and "different students may well learn different things from the same experiences" . According to constructivist theory, individuals construct meaning from their experiences for the purpose of explaining and making sense of real world phenomena. One implication is that when students enter a new learning situation, they already have notions and prior knowledge or understanding of the world. Because these prior notions are usually not compatible with accepted scientific theory or knowledge they have been referred to as alternative frameworks, naive theory, or misconception (Cleminson, 1990). The ability of students to learn new concepts is dependent upon the extent to which they are able to change these alternative frameworks for frameworks of scientific knowledge depicted in classrooms (Duschl, 1990). Carey suggests that cognitive development involves conceptual change and hence in Duschl's (1990) comparative analysis, the way children learn science is found to be remarkably similar to the process of growth of scientific knowledge activity. Both processes are seen to be developmental and both involve constructing meaning, revision, alteration, and/or replacement of ideas with new and more plausible alternatives.

Science instruction has accordingly been described as a process aimed at conceptual change achievable when students are actively involved in the process of doing science and are guided to change their current alternative frameworks for more acceptable frameworks, ideas or theories (Carey, 1986; Duschl, 1990). The conceptual change developmental model or the alternative framework of teaching involves students in processes involving physical skills, imagination and creativity in tackling the usually ill-defined problems and events of the real world. Burbules and Linn (1991, 229) corroborating this line of argument call for real-time investigation "carried out in the context that replicates the experiences of practising scientists". .It is within this context that science curricula are re-orienting themselves from content to method, from products to processes (Hodson, 1985). Both the methods and processes of science, and the process of learning science have their foundation on prior knowledge or the work of others and hence the centrality of subjecting preliminary work of others to a broad based review, critique, refinement, and revision processes similar to higher order intellectual processes which many current science curricula seek to develop with students (National Research Council (NRC, 1992).

Nature of Science and Science for All: Myth or Reality?

The review suggests that modern courses are not particularly successful in meeting their declared goals for which it has been suggested that teachers' inadequate conceptualization of the NOS and some degree of confusion in the philosophical assumptions in contemporary science curricula are the most contributory factors (Tamir, 1983; Duschl, 1988; Hodson, 1988). Teaching styles have not changed as rapidly as expected. For example, while the teaching style and the teacher's image of science are known to be greatly influential on their students' attitudes to science (Tamir, 1983; Akindehin, 1988; Cleminson, 1990; Duschl and Gitomer, 1991; Gardner and Young, 1983; Linn, Songer and Lewis, 1991; Songer and Linn, 1991), teachers understanding of the NOS is little better than that of the students (Hodson, 1988). This would suggest that both pre-service and in-service science teacher education have not been effective.

It is informative to now examine the range of implications arising from the new understanding of the NOS as they relate to science teacher pre-service to in-service preparation. Wagner (1983,612) asserts that science education must "require that students adopt both the language and the physical practices co-extensive with present research paradigms and finally, it must require students to direct considerable attention to the acquisition of a critical spirit. Hodson (1990) echoed the same sentiments by requiring that for science education to be epistemologically informed, it must look to the HPS. Cleminson, (1990 , 437) states categorically that "the science educator must, in his/her own way be a philosopher of science in order to provide effective science teaching". Akindehin (1988) asserts that modern science education should focus on the NOS, the factual content of science the processes of science, and science-related attitudes which can only be attained if teachers develop an understanding of the NOS during their training. Traditional science content classes and science methods courses are perceived as incapable of developing desired attitudes towards science and understanding of the NOS. Duschl (1985, 548) made a point that

> The concept of making science education an inquiry into inquiry was and still is a viable idea .

According to this view, in addition to correcting the currently distorted image of science, the "new" approach will be effective in reducing the "flight" of both teachers and students from the science classroom and make science education for all attainable (Duschl, 1988; Hodson, 1988; Mathews, 1990). The arguments of Entwistle and Duhnworth (1972) and Brush (1979) (cited in Hodson, 1988) suggest that when science is seen to be more person-oriented and emphasizing humanitarian aspects of science both the attitudes and recruitment to optional science courses improved. Mathews cites studies of Brush (1989), Russell (1981), Aikenead (1974), Holton (1978) to illustrate the success enjoyed by Harvard Project Physics which used HPS ideas over non-HPS curricula developed about the same time (1950s-1960s). That both the theory and practice of science education are more and more getting informed by the HPS, a condition which Mathews (1990) calls "rapprochement", is evident in Australia, Denmark, England, Wales and the United States of America where some HPS-incorporating science education curricula are reportedly increasing in number.

Mathews (1990) cites evidence to suggest that through formal training, as the case with scientists, it is possible to behave and think scientifically but without an understanding of the basic NOS and its aims. Similarly, it is possible to have graduate teachers who may be able to think scientifically without understanding the NOS. HPS is thus seen to impinge more upon methodological and pedagogical approaches to science instruction rather than upon subject matter, and thus should be deliberately taught. The philosophical orientation of the teacher determines the approach and ways students will be initiated to science. Those few countries in which HPS has started making its impact, have incorporated it as themes in the approach to subject matter and teaching of the curricula in some science teacher education preparation programs.

The intention of looking to HPS is so that science can be taught in its social, historical, philosophical, ethical, and technological contexts prompting proponents to suggest that science education should be an education about science as well is in science (Hodson, 1988; Mathews, 1990). The focal points of such courses perhaps can be reasonably represented in the following list of statements about the abilities which 14-16 year olds should have after following National Curriculum Council's new curriculum in science in the U.K. (Mathews, 1990, 27):

> distinguish between claims and arguments based on scientific data and those which are not; consider how the development of a particular scientific idea or theory relates to its historical and cultural, including the spiritual and moral context; and study examples of scientific controversies and the ways in which scientific ideas have changed.

The AAAS's *Science for all Americans: Project 2061* also significantly addresses similar issues. The conclusion that can be drawn is that HPS is not without precedent or success in developing an authentic understanding of the NOS.

Implications for a Post-Independence African Context

Linn, Songer, and Lewis (1991) observe that:

> more and more science educators are examining the history of science and considering philosophers' interpretations of scientific and theory change. While the interest is not new, the serious incorporation of work in the HPS is a substantial departure from past practice.

In African systems which are frequent importers, adopters and adapters of S & T, there is need to ensure that change and progress in the area of science education are in line with change in HPS but with obvious contextual adaptations and modifications. What then are the possibilities and justifications for an African context?

The need for an approach that develops an awareness of the NOS and how scientific progress occurs is probably more obvious in systems which are often taken for granted to be completely accommodative of the western world view. Students in Africa embark on science courses already possessing substantial constructed views of the world which are not western in scope and thus will have distorted perceptions of the NOS. Even in the West, children's prior knowledge of science is that of a collection of facts to be memorized. Their views on scientific explanation and learning , and their perception of models are often inconsistent with the work of scientists (Linn et al., 1991).

Ogunniyi (1988) asserts that in modern science education there is a need to relate science more closely to the learner's societal and cultural environment so as to minimize possible conflicts that arise between the learners views of the world and that accepted in western science. In his analysis, there are obvious distinctions between African traditional thought and scientific modes of thought. Indigenous knowledge systems and African views of reality are based on people, are shrouded in secrecy, and are embedded in religion and thus African thought is rational but metaphysical. In the traditional African view of the world concept of causality and effect is based upon a different logic from that of western science. For example, typically, disease and death are construed as being a result of some divine intervention.

Ogunniyi, (1988) observes that the traditional system of thought and the scientific system of thought may not be mutually exclusive in the same way a western scientist might hold the scientific view and the Christian view. The scientific world view may not be able to displace completely the traditional world outlook. Another relevant finding from an analysis of studies on Nigerian subjects was that an exposure to "a well organized history/philosophy of science that emphasizes a scientific world view does enhance the peoples' orientation towards the view" and that "the traditional world view could be enlarged to accommodate the scientific point of view" (Ogunniyi, 1988, 4).

The implications for conceptual change teaching is apparent from this comparative analysis. According to this teaching model, learning is viewed as an active process in which the learner is engaged in constructing or generating concepts and involves organisation and restructuring of concepts and theories that the learner already has (Cleminson, 1990; Duschl and Gitomer, 1991). Teaching is accordingly seen as a process which must facilitate and influence conceptual change in which the learner is responsible for restructuring knowledge thus helping to ameliorate differences that exist between children's theories, their personally derived meanings of scientific concepts, and those perspectives and theories held by scientists.

The necessity and desirability of changing the traditional view for a scientific view is obvious although others might construe that as reflecting rejection of a culture or as dominance of one culture by another. Paradoxically, the schooling enterprise is both explicitly and implicitly based on this justification. In Africa as in other developing countries, the scientific world is often interchanged with 'modernism'. A society undergoing change from an agrarian to a technological economy is deemed to be modernizing (UNESCO, 1983; Ogunniyi, 1988). Zimbabwe is a case in point in which the object of science curricula is to modernize agricultural and industrial production (MEC, 1992).

For science teachers it is important to recognize and appreciate African cosmology and the restrictions it might place in their efforts to develop STL. In this respect an approach in which both views are presented and students are asked to weigh and argue the merits and demerits of each is desirable. As part of methodology in science courses, this would provide preparation for the African classroom in which the two views are likely to be both present. A further consideration is the now accepted notion that science taught in schools differs both from 'real science' and from every-day life while it shares the characteristics of both (Reif and Larkin, 1991).

It is imperative that Africans have an accurate understanding of the NOS and its applications manifesting itself in or as technology for that will impinge upon their capabilities to develop, adapt or to chose appropriate technology. Paul Hurd (1990) in an editorial in Science Education observes that S & T have become an integrated system and that research is now more social than theory driven. It thus requires solving problems of societal concern through application of scientific knowledge and technology. Advances in science are seen as propelling the economy and therefore requiring education for life, living, learning and working in the twenty first century. Hurd underscores the need for an HPS based approach by observing that skills in the utilization of knowledge will outrank those characteristic of inquiry. Hurd(1990, 413) concludes by pointing out that

> these changes and others have made obsolete much of the existing research in science education and nullified its current philosophical base .

Further, when looking at creativity, it is often defined in terms of western standards, norms and processes although according to UNESCO it is little encouraged in many African science classrooms. UNESCO (1983) observed that the creativity in science is little encouraged except for the few students who are voluntary members of science clubs or societies that meet outside school hours or at weekends. Members are encouraged and helped to work on research projects of their own in laboratories, in workshops, or in the field sometimes leading to a science fair or exhibition. As stated in the UNESCO book on *Science and Technology Education and National Development*:

> the evaluation of such young scientists' programs has shown that they have had strong beneficial effects in stimulating creativity, in helping youngsters to plan and carry out their work more or less independently, in strengthening motivations to enter scientific and technical careers, and discovering hidden talents.

Science fairs and young scientists exhibitions can and should increasingly become conventional approaches by which science is presented to African children.

Developing and enhancing creativity and problem solving should probably be the most important goal for African systems which often seek to use S & T education as preparation for the world of work (UNESCO, 1983; MEC, 1992; Nichter, 1984) and given that these goals are in fact required and expected in the workspace (Hurd, 1990). On the science curriculum and the world of work, UNESCO asserts that:

> the teaching of science and technology for development should be geared to self-employment or to existing employment. In either cases the teaching should include a strong functional element, not merely function-oriented knowledge and skills but also a technical knowledge related to creativity and productive work .

In many African systems S & T are thus seen both within national development and for national development hence according to Chisman (1984) scientific literacy has practical economic consequences. This situation might be exemplified with reference to Zimbabwe where the goals of secondary education emphasize the preparation of pupils for the world of work. The general introduction to the science syllabus Science (5006) and Extended Science (5007) (reference SS10 (ZIMB) 1992) highlights "education which will be functionally useful in the world of work",and a philosophy of education with production aimed at helping pupils relate knowledge and theory to their practical application in production. The "essential general knowledge" is described in terms of social, scientific and technological content and concepts that should be accessible to all consistent with current international views in science education.

Practical applications are divided into five sections consistent with aspirations to develop STL in a real-world context in themes such as 'Science in industry', 'Science in agriculture', and 'Science in the community'. The impact of this curriculum innovation has been marked particularly for Southern African Development Coordination Conference (SADCC) countries adopting it (International Foundation for Education with Production (FEP, 1990). FEP stresses that the syllabus aims to engage students in economically purposeful productive work and socially useful activities alongside academic and theoretical study. Like in Zimbabwe, many African science systems have contextually appropriate science curricula (Ogunniyi, 1986). The authors of the Five Year National

Development Plan (1991-1995) in Zimbabwe lay nearly all hope for socio-economic advancement on S & T. They state:

> Development of Science and Technology is Zimbabwe's long term and most important strategy for economic and social development.

Building a Support Base for Successful S & T Educational Programs

While great potential exists for African nations to achieve STL for all, it is imperative that they recognize and work feverishly to institute a support base for S & T education. Many African education systems have a common thrust of remarkably increasing relevance of their educational programs at independence but paradoxically decreasing the effectiveness of the programs with time and as novelty of independence waned. The following arguments articulate potential requisites that could serve to provide a support base, often neglected, for progressive S & T programs in schools and in science teacher preparation institutions.

First we might begin by setting up and expanding the role of science education professional societies. In the developed nations, the re-education or continuing education of science teachers is stimulated and influenced by science teachers themselves through professional associations for science teachers and science educators (UNESCO, 1983; Chisman, 1984). The Association of Science Educators in the U.K. and the National Science Teachers Association in the U.S.A. give definitive policy statements about the direction science education should take. Such organisations publicly debate the place of science in the curriculum, development of school curricula and implementation strategies of various courses, and in general share experiences on classroom practice and problems. Only one or two organisations exist in many African countries if at all. While the fewer might be the better in reaching consensus for courses and programs of action, in Africa very few professional organisations contribute to needed change (UNESCO, 1983). As observed by Ogunniyi (1986), African science education is often dogged by the lack of participation by professional scientists unlike elsewhere in the world.

In Zimbabwe the following picture of instructional practice, which can easily be supported or corrected through activities of professional societies, has recently been reported in a recent survey of 74 secondary school science teachers in Harare region (Shumba, 1992a). Despite the difficult conditions under which science teachers served, they had positive attitudes toward science teaching, pupils' learning and for in-service staff development and training. While they perceived that training could improve their teaching competency and increase their professional growth, opportunities for INSET were seen as not readily available. While both the official curriculum and assessment objectives emphasize higher order learning and functional literacy (see syllabus SS10 (ZIMB), 1992), current teacher practice does not appear to reflect this (Shumba, 1992a). The majority of respondents lacked confidence and rarely used the 'individual practical', 'individual project or study', and 'free inquiry' which require individualization of instruction. Of the ten professional interaction categories, the majority of science teachers interacted least frequently in team teaching, observing and critiquing colleagues teaching, and discussing student progress. Respondents interacted more frequently in aspects relating to the preparation and planning for teaching and least frequently in matters requiring reflective and critical appraisal of their teaching or student performance, which are critical aspects in instruction and assessment (Shumba, 1992a). The tentative results of the study suggested that the level of science teacher professionalism should be a sufficient concern in Zimbabwe where it is not helped by the low level availability of instructional leadership in secondary schools (Nyagura and Reece, 1989), by science teacher professional courses which are fairly traditional in their approaches to methods of science teaching (Haeck, 1990) and by external teaching practice assessment practices that are not professionally sound (Shumba, 1991a).

According to UNESCO (1983) a professional association endeavors to develop and extend the profession by assisting its members keep up to date in their subject, by informing the public at large of the significance of the profession in contemporary society, and by relating the profession to government or to other official organisations. Journals and bulletins of science teachers' associations are an essential communication channel which can carry papers on scientific content related to teaching methodology, and articles on how to teach, how to make and how to use new teaching aids. In Zimbabwe, the *Teachers Forum* tends to assume this rôle but on a narrow, general and broad basis since it caters for various subject areas at both secondary and primary level. A single source and a singular approach is simply too limited.

Further, in other countries, the professional autonomy enjoyed by science teachers is effectively negotiated and guaranteed by and through their professional associations, and indeed the ruling class is likely to yield to calls for change in professional practice when pressed by a professional association rather than by individuals. In analyzing the educational practices of Cuba and Zimbabwe based on socialist and command economic policies Dzvimbo (1991) recently raised issues pertaining to decentralization, autonomy, and participation. These are commonly lacking in many African contexts yet these factors are known to "inhibit innovativeness, independence and the advancement of democratic principles" (Dzvimbo, 1991, 304). Consequential effects of this are best captured in this quote:

> ... decentralization is critical. In fact, a centralized educational plan dissuades participation of civil society in plan making. Teachers who are crucial in implementing educational plans tend to be marginalized in the conceptualization process thereby making it remote for them to own the plan which is crucial in the implementation stage. Centralized planning also engenders apathy because the planners assume that people especially peasants do not know what they want.

Social transformations in Africa under various economic structural adjustment programs should provide ample opportunity and conditions less hostile to changing science education practices and raising the professionalism and autonomy of science teachers significantly through professional societies.

Second, we will need deliberate efforts aimed at reforming and revamping both the pre-service and in-service science teacher education provision so that it articulates with and supports pre-college curricula. The negative influence of lack of vertical articulation is a major hypothesis being tested in Zimbabwe (Shumba, 1992b). It is clear that if teachers are to promote an adequate understanding of the interdependent relationship among science, technology and society it is important that they understand the NOS and how science knowledge is generated.

UNESCO (1983) asserted that in the less developed countries the universities and teacher-training colleges have the capacity to influence S & T education positively and help it go in the right direction yet they remain aloof and unchanging:

> ...during a time when many new ideas have sprung up at the school level. For example, manual work and community orientation have been introduced into the school curriculum for a variety of valid purposes. But teacher-training colleges have not responded by re-forming preservice development (UNESCO,1993,136).

There is urgent need to design training programs which are in harmony with and supportive of the new ideas in school education.

Third, science teacher preparation curricula have to respond by seriously incorporating the HPS in their methodology courses. Haecks's (1990) study of science teacher education methodology courses is probably the most informative current data on practice in the secondary teachers colleges in Zimbabwe. The methodology courses in which philosophical issues are addressed are only with respect to the current but local science curricula and thus are limited in scope. In the developed world, Hodson (1988) observes that teachers remain ill-informed about basic issues in the philosophy of science. Hodson cites Elkana (1970) who claimed at the time that teachers views predated contemporary philosophical views of science by as much as twenty to thirty years. According to Hodson (1988):

> There are now several generations of serving teachers with little or no understanding of basic issues in the philosophy of science and their significance in the design of learning experiences.

We need a broad based understanding of HPS on which we can build our children's understanding of basic issues in the nature of S & T.

Fourth, African nations will need to work feverishly to overcome underdevelopment and project planning and management problems which are often cited as the most common impediments to UNESCO science improvement projects in Africa (Nichter, 1984; Ogunniyi, 1986). Underdevelopment is characterised by low economic growth, low technology, minimal reserves of foreign exchange, and poor communications (Nichter, 1984). Consequently, projects lacked facilities and lacked a wide assortment of resources such as printed materials, the problem being more serious at school level compared to university or college level. Zimbabwe shares many of these problems. While observing that there is a direct relationship between a science program that emphasizes 'hands-on' problem solving by experimental investigations and the need for apparatus, equipment and consumables the situation is negative in most of the Anglophone countries in Nichter's (1984) research.

Fifth, while in many countries there is talk about 'self reliance' and teachers who can utilize and improvise from local resources this is perhaps a myth when it comes to real practice particularly in Zimbabwe (Shumba, 1991 and 1992a). Nichter (1984) makes the pertinent observation that teachers who lack successful experience from working with real laboratory equipment are unlikely to be able to improvise. The conditions in schools, particularly teacher shortage and large classes made it impossible for student teachers to see relevance of activity based methodology their professional training advocated. Improvisation is further impeded by the teachers concerns with the basic form and approach to the science curriculum for which they have not received formal training, pre-service or inservice (Hodzi, 1989).

Hodzi (1989) found that teachers trying to implement the new thematic curriculum in Zimbabwe were concerned with the basic understanding of the themes and their content which for the developers were 'basic' issues. This underscores the significance and need for formal training in curriculum and instruction, which can be supported with the relevant study of the HPS. Further, where local low cost science kits such as

ZIMSCI have been developed, both teachers and students may consider the innovation as cheap and inferior (Wright, 1982) for example when teacher training colleges being better equipped have not used them with their trainees. While importance of involving teachers in the curriculum development process is acknowledged in Zimbabwe as in many countries in Africa, we find various curriculum development centres working with and guided by the centre-periphery model which does not take partnership between developers and teachers seriously.

The second problem (Nichter, 1984), underestimating the process is really a problem of system change and system building which must start with a thorough appreciation of the existing basis for development. Inadequate planning, inadequate consideration and forecasting of implementing problems, and poor coordination in the African countries appear to be common phenomena which must be reversed if substantial qualitative changes to the education systems is to be effective. This is more pertinent in S & T education where a relatively high degree of technical sophistication is essential. For example little funds are earmarked for staff development and training, and in-service training of teachers and often political leaders put pressure for projects to produce results in too short a period other than those identified by developers, thus the pace of implementation is pushed to the extent that it exceeds the capabilities of the country (Nichter, 1984). A rather counterproductive scenario occurs when those responsible for teacher training are not responsible for syllabus development and control, a situation which needlessly creates coordination problems and vertical articulation problems as the case in Zimbabwe (Shumba, 1992a).

Sixth, African systems will need to view S & T curricula in conjunction with instruction and assessment not in isolation. While Nichter's (1984) review demonstrates that the African systems have rejected the European model of education as inappropriate, there remains strong and notable attachment to that system, e.g. emphasis on the Cambridge School Certificate external examinations which undesirably set the tone of instruction and of the students learning (Nichter, 1984). Substantial changes in the context of instruction is evident but the status quo remains intact in the methods of instruction, assessment and evaluation. In Zimbabwe the Ministry of Education and Culture is frantically trying to localize examinations without substantive changes to the scope and purpose of examinations. Such a limited transformation will be guilty of changing only the venue, and the nationality of examination script makers. For example, examinations are seen essentially as a weeding out mechanism where progressively, fewer and fewer students are selected for the next academic ladder, various vocational options and scanty middle grade jobs. Lewin (1984), reviewing reforms in Sri Lanka and Malaysia which have British style education systems comparable to Zimbabwe, showed that "the examination tail wags the educational dog" and that "school examinations have come to dominate social-role selection". Trends elsewhere in the world are for assessment to serve functions related to instruction rather than selection. Assessment can do this by providing feedback on attainment of desired educational standards by each and every student (NRC, 1992). Developing nations will need to be responsive to the role of classroom-based assessments if STL for all is to be realized and for which greater autonomy and professionalism in the way teachers perform their work will be necessary.

Last but not least, Zimbabwe like many African systems discerns the need for graduate science teachers but fails to plan, develop, and budget for unambiguous programs to produce graduate science teachers. For the secondary school sector, it is estimated that under four percent of teachers in all subject areas are degree holders. In fact planners appear to have a rather ambiguous perception of graduate science teachers. For example in the Second Five Year National Development Plan 1991-1995,the impression is given that the Bachelor of Education (Science) programme sponsored through the Zimbabwe Science Teacher Training Project (ZIMSTT) is sufficient to address the secondary sector's need for graduate science teachers to handle the mammoth task of S & T education innovation and implementation. The fact that ZIMSTT trained teachers end up servicing this sector is incidental rather than intentionally devised. Combining biology, chemistry and physics, the programme could originally produce an average of sixty teachers annually on the one year format and can now only produce an average of sixty teachers in two years (Jaji and Hodzi, 1991). From 1986 to the present, the programme has not expanded at all and thus our national plan does address itself to the need for a sound S & T base for economic development but fails to provide budgetary provisions for realization.

Advanced level ('A' Level) science may not even be the crucial sector of secondary S & T education to concentrate focus upon unless of course the intents are to retain the academic orientation of education of the past. 'A' Level students are a relatively mature and academically talented pool of individuals who have already elected to pursue the advanced study of science academically and, may be, professionally. The first four years of secondary education require services of knowledgeable graduate science teachers, deliberately trained and prepared with that sector in mind. Currently, this sector is served by a few graduate science teachers who entered the teaching profession as a second or even third career option or after failing to secure employment with the commercial and industrial sectors. This situation is not unique to Africa (see for example Glass and Aiuto, 1992). This is conjectured to be largely the case with many students graduating at the University of Zimbabwe through the Faculty of Science and who end up having to serve as teachers. While those choosing to become science teachers have opportunity to go through an additional year of professional preparation for the Graduate Certificate in Education it is important to note that they choose teaching as a second option and late in their education. Programmes in the Faculty of Science are not designed to train science teachers and in the future some of them probably should.

There is thus great potential for S & T education to blossom in Africa but this potential is diminished by human made problems such as poor planning, myopic judgment and incoherent administration and management which many are not ready to admit. Loving (1991, 823) assert that decisions on what to teach and what to eliminate require a deeper understanding of what science is and is not. This paper has highlighted the evident increasing emphasis for student teachers to study philosophy of science particulary in their methodology courses. Collette and Chiapetta (1989) (cited in Loving, 1991) assert that

> we cannot expect our students to understand the laws, concepts, principles, and theories of science without first having an understanding of how they were derived.

For African systems, the notions advanced by Duschl and Gitomer (1991) appear particulary relevant if a comparative approach which addresses also the traditional African way of knowing is used. (Ogunniyi, 1988).

Emphases in the school science curriculum should include knowledge about science; how and why we know; knowledge growth and the role of explanation; and contextualized problem solving. Further, it must seek to show the impact of S & T, must attempt to forge better links between scientific research, education and the world of work, and must fully explore the potential of S & T for national development. In order to accomplish this, both graduate and non-graduate pre-service teacher preparation programmes need to produce 'educated' teachers not 'trained' teachers. Educated science teachers will have knowledge of "terms of their own discipline - 'cause', 'law', 'explanation' 'model', 'theory', 'fact'; ... knowledge of the often conflicting objectives of their own discipline - to describe, to control, to understand; ... knowledge of the cultural and historical dimensions of their own discipline" (Mathews, 1990,. 39). This knowledge can be gained through a study of the HPS. It is also imperative that African systems examine students' and teachers' understanding of the NOS in relation to the influence by their indigenous knowledge and belief systems; and to examine courses of action by which greater professionalism, autonomy, and participation of science teachers might be achieved.

REFERENCES:

Akindehin, F. (1988). Effect of an instructional package on pre-service science teachers understanding of the nature of science and acquisition of science related attitudes. *Science Education 72(1)*, 73-82.

Burbules, N.C. and Linn, M.C. (1991). Science and philosophy of science: congruence or contradiction? *International Journal of Science Education, 13(30),* 227-241.

Carey, S. (1986). Cognitive science and science education. *American Psychologist, 41*,1123-1130.

Chiapetta, E.U., Sethna, G.H., & Fillman, D.A. (1991). A quantitative analysis of high school chemistry textbooks for scientific literacy themes and expository learning aids. *Journal of Research in Science Teaching 28(10)*, 939-951.

Chisman, D.G. (1984). Science education and national development. *Science Education, 68(5)*, 563-569.

Cleminson, A. (1990). Establishing an epistemological base for science teaching in the light of contemporary notions of the nature os science and of how children learn science. *Journal of Research in Science Teaching 27(5)*, 429-446.

Driver, R. (1981). Pupils alternative frameworks in science: *Journal of Science Education, 3*, 93-101.

Duschl, R.A. (1985). Science education and philosophy of science twenty-five years of mutually exclusive development. *School Science and Mathematics, 85(7)*, 541-555

Duschl, R.A. (1988). Abandoning the scientific legacy of science education. *Science Education, 72 (1)* 56-62.

Duschl, R.A. (1990). *Restructuring science education: the importance of theories and their development*. New York: Teacher College, Columbia University.

Duschl, R.A. and Gitomer, D.H. (1991). Epistemological perspectives on conceptual change: implications for educational practice. *Journal of Research in Science Teaching 28(9)*, 839-858.

Dzvimbo, K.P. (1991). Education for liberation and development: a comparison of Cuban and Zimbabwean education practices. *Zimbabwe Journal of Educational Research 3(3)*, 281-308.

Edmund, N.W. (1992). *The general pattern of the scientific method (SM-14).* Ft Lauderdale, Florida: Edmund Scientific Company.

Gardner, M.H. & Yager, R.E. (1983). Ameliorating current problems in science education. *Science Education 67(5),* 587-594.

Geddis, A.N. (1988). Using concepts from epistemology and sociology in teacher supervision. *Science Education, 72(1),* 1-18.

Glass, L.W. and Aiuto, R. (1992). An agenda for action in pre-college science teacher education reform. Discussion Paper for Science Deans and Science Educators Conference, Indiana University, Indianapolis: Indiana, September 25-26, 1992.

Haeck, W. (1990). Training science teachers: a comparative study of methods courses in the science departments of four secondary teachers colleges. Unpublished Diploma in Education Thesis. University of Zimbabwe, Harare.

Harms, N.C. & Yager, R.E. (Eds.) (1981). *Project Synthesis: What research says to the science teacher, volume 3.* Washington D.C. National Science Teachers Association.

Hawkins, J. and Pea, R.D. (1987). Tools for bridging the cultures of everyday and scientific thinking. *Journal of Research in Science Teaching, 24 (4)*, 291-308.

Hodson, D. (1985). Philosophy of science and science and science education. *Studies in Science Education, 12(1985)*, 25-57.

Hodson, D. (1988). Toward a more philosophically valid science curriculum *Science Education 72(1),* 19-44.

Hodzi, R.A. (1989). Assessment of Teacher Needs for Implementation of Zimbabwe New O Level Syllabus. *Zimbabwe Journal of Educational Research, 1(3),* 377-401.

Hurd, P. (1990). Change and challenge in science education. *Journal of Research in Science Teaching, (27(5),* 413-414.

International Foundation for Education with Production (1990). *Education with production curriculum*. Gaborone, Quick Print.

Jaji, G. and Hodzi, R.A. (1991). Tracer study of the Zimbabwe Science Teacher Training Project. *Zimbabwe Journal of Education Research, 4(2),* 164-183.

Lewin, K. (1984). Selection and curriculum reform. In Oxenham, J. (ed) (1984), *Education versus qualifications? A study of relationships between education, selection for employment and productivity or labour*. London: George Allen and Unwin.

Linn, M.C., Songer, B.N. and Lewis, E.L. (1991). Overview: students models and epistemologist of science. *Journal of Research in Science Teaching 28(9),* 729-732.

Loving, C.C. (1991). The scientific theory profile: a philosophy of science models for science teachers. *Journal of Research in Science Teaching 28(9)*, 823-838.

Mathews, M.R. (1990). History, philosophy and science teaching: a rapprochement. *Studies In Science Education. 18(1990)*, 25-51.

Mayer, R.E. (1983). What have we learned about increasing the meaningfulness of sicne prose? *Science Education, 67(2),* 223-237.

Miller, R.M. (1984). Science teaching for the children of the future. *Science Education 68(4),* 403-410.

Ministry of Education and Culture, (1992). *Science 5006 and Extended Science 5007 Syllabus @@10 (ZIMB) 1992.* Harare, Zimbabwe: Ministry of Education and Culture.

National Research Council, (1992) National Science Education Project, Status Report, Fall 1992 (draft).

Nitcher, R. (1984). A study of UNESCO science education improvement projects in selected Anglophone countries of Africa: project problems. *Science Education, 68(4)*, 381-396.

Nyagura, L M & Reece, J.L. (1989). The school head as an instructional leader in Zimbabwe secondary schools. *Zimbabwe Journal of Educational Research, 1(3),* 304-341.

Ogunniyi, M.B. (1986). Two decades of sicne education in Africa. *Science Education, 70(2),* 111-122.

Ogunniyi, M.B. (1988), Adapting western science to traditional African culture. *International Journal of Science Education, 10(1),* 1-9.

Paulson, F.L. and Paulson, P.R. (1991). This ins and outs of using portfolios to assess performance Unpublished Manuscript.

Reif, F. and Larkin, J.H. (1991). Cognition in science and everyday domains: comparison and learning implications. *Journal of Research in Science Teaching 28(9),* 733-760.

Republic of Zimbabwe, (1991). *Second Five Year National Development Plan, 1991-1995.* Harare Government Printer.

Shumba, O. (1991a). Teaching Practice: An Overview of the findings of External Assessors. *Zimbabwe Bulletin of Teacher Education,* (Manuscript accepted January, 1991).

Shumba, O. (1991b). Curriculum implementation in primary schools without curriculum leadership: the folly of a system. *Zimbabwe Bulletin of Teacher Education,* (Manuscript submitted November, 1991).

Shumba, O. (1992a). Perceptions of science teachers on teaching competencies: an exploratory study focusing on Harare Region. *Occasional Paper Zimbabwe Bulletin of Teacher Education* (Manuscript Accepted December, 1992).

Shumba, O. (1992)a. *Vertical articulation in teacher's colleges and secondary level science education* ,University of Zimbabwe Research Board Vote No: 2.9951.10/N026.

Songer, N.B. and Linn, M.C. (1991). How do students view of science influence knowledge integration? *Journal of Research in Science Teaching, 28(9),* 761-784.

Tamir, P. (1983). Inquiry and the science teacher, *Science Education, 67(5),* 657-672.

Tehart, E. (1988). Philosophy of science and school science teaching. *International Journal of Science Education 10(1),* 11-16.

UNESCO, (1983). *Science and technology education and national development.* Paris, United Nations Educational, Scientific and Cultural Organisation.

Wagner, P.A. (1983). The nature of paradigmatic shifts and the goals of science education *Science Education,67(5),* 605-613.