1. Introduction.
The developed world enjoys global economic predominance as a result of their technical superiority that is dependent on their human resource who are scientifically literate. Africa's economic woes are often blamed on the education system, in particular science education that does not prepare students adequately to meet the challenges of today and spearhead technological, economic and social development.

Science education in Africa faces problems such as poor performance by students in science. This results in very few students taking science at higher levels of learning. Added to this, low morale among teachers and low expectation among students compound the crisis.

2. The socio-cultural background of an African child.
Before we look at science teaching strategies, let us consider the socio-cultural background of an African child who comes to the science lesson. Over 80% of the population of Africa, including children, lives in rural areas.

In traditional African society, the socio-cultural environment of children is defined by an authoritarian society. The knowledge and wisdom resides in the older generation. The youth are considered to have nothing to offer. In fact children who are too inquisitive and ask too many questions are branded indisciplined, badly brought up and mannerless. This is largely because the questions that children ask, most of which are perfectly legitimate and genuine, may embarrass the older generation including their parents and grand parents. The older generation believe this would undermine their authority. It is shameful for an African elder to be told that the younger generation have more knowledge than he has.

Thus most African children grow up as passive, submissive, non-critical beings as a sign of politeness, obedience and good manners. It is not uncommon in African schools, especially in rural areas, to see very bright children who are too critical and who ask too many questions pertinent to the lesson of the day being punished for
being naughty. Such punishment may be entered in the child’s end of term or year report from the school to the parents, who may in turn administer further punishment to the child for not being a good boy or girl at school.

Teachers belong to the rank of elders, and therefore their authority and knowledge should not be questioned by a school child. A learner with such an African background would need re-orientation of socio-cultural attitudes in order to fit into the science culture taught in schools, where learning can depend on the learner being inquisitive, asking questions, proposing possible explanations (hypotheses) and carrying out investigations to test the hypotheses.

At times, some children compromise, to have ‘class culture’ when they are in class, and ‘traditional culture’ when outside the class. As Gallegos et al (1994) point out, children therefore react according to the demands of whichever culture they find themselves in. This creates a ‘duality of cultures’ in the mind of the learner. The socio-cultural practice may affect science learning, which thrives in the environment of a questioning and inquiring mind. Constructivism cannot be nurtured by passiveness. However, it is in this setting that the study took place, and in which its recommendations are sited. This is the African child we are talking about.


The major aim of science education is to help students become good at “scientific thought.” From a teaching and learning perspective, research is helping educators to better understand the nature of scientific knowledge by shifting their beliefs away from the notion of science as a collection of facts and processes to one in which science is a useful tool for everyday experience.

Traditionally, scientific knowledge was generally perceived as a collection of statements about the world. Recently, however, teachers are recognizing that scientific knowledge provides conceptual and technological tools that allow people to describe and explain how the world works with precision, and to achieve a better understanding and appreciation of the world they experience. Unfortunately, traditional science classrooms and textbooks usually present scientific facts, formulas, and definitions as a body of content to be mastered. Children come away from their science classes with the belief that the goal of learning science is to allow scientists to acquire this
knowledge. The result is that children do not attain conceptual understanding. They remain unable to apply science to their own experience and therefore see little value in pursuing these studies with vigour. If this trend continues the results will be devastating for Africa. A highly technological society depends on people who can engage in scientific thought through which they can solve the various problems that face mankind. We cannot afford to turn kids off from meaningful learning of science in our schools.

How can educators provide children with meaningful science learning? We must transform our science into an inquiry-based culture, a community of explorers, where curiosity, creativity, and questioning are valued, where resources and opportunities are made readily available, and where students can work, like scientists, engaged in the process of doing science. Critical thought develops in this culture as new ideas are encouraged. Children come away from these experiences with the ability to use scientific knowledge to describe, explain, predict, and control their world.

Students develop informal "theories" and "hypotheses" about why certain phenomena occur based on their own observations and experiences out of and in the school. Sometimes their knowledge is on the right track, sometimes it is completely wrong. Successful teachers respond to this challenge by studying their students, learning how they think about the world in general and about the particular topics that they study. With this knowledge, teachers can guide their students through the complex and difficult process of conceptual change.

Learning is not necessarily an outcome of teaching. Teachers must strive to help students develop understanding (not just recall) and must develop assessment strategies to measure this understanding. They must base their curriculum (planning for teaching) around the "less is more" principle that involves identifying and emphasizing the most important concepts and skills, that concentrates on the quality of understanding rather than the quantity of information. Understanding occurs when students make connections between concepts or ideas. Concepts are learned best when they arise in a variety of contexts, are presented in a variety of ways, and when students have a chance to use them on a variety of tasks.
Learning generally occurs from concrete to abstract. Science involves representing one’s understanding of the physical or concrete world in abstract symbol systems. Therefore, learning should proceed from common, describable experiences to the development of symbolic and abstract representation.

Effective learning requires feedback. Students must be able to feel free to express ideas and to receive analysis and comment from their peers. This feedback provides the gist for students to reflect on their ideas and performance, and see relationships among items of knowledge and to test their validity.

Expectations affect performance. The culture of the classroom must provide support and encouragement for the belief that all students can think like scientists. When students get the message that they cannot achieve, the likelihood is that they will not achieve much.

Teaching is a difficult and complex art. It is an inherently complex and demanding process for which simple rules are insufficient. Successful teachers must build classroom communities in which students work productively to achieve understanding. For most teachers, this will be possible only if they have an extensive base of knowledge about their areas of competency (subjects), about their students, and about teaching (pedagogy). They should have the ability to facilitate learning in a community of student scientists. They should have adequate teaching materials and should enjoy support and encouragement from administration. They should have ample time to prepare, to respond to students, and to reflect on their teaching.

4. Research Findings on Teaching and Learning of Science.

The Area of Study

This paper sites part of a research carried out by the author in Kenya to find out the children’s conceptions and understanding in a scientific concept area of organic decomposition and its application on food storage and preservation. Traditional and modern food storage and preservation methods is one of the topics taught in primary school science and secondary school biology in Kenya. At the same time, children are familiar with decomposing things, both animals and plants in their environment. They see dead dogs, zebras, snakes and plant materials such as leaves lie around for some while and then disappear except for the bones of animals that lie around for a
longer time. They are familiar with food such as meat, fish, milk and grains going bad in their homes if not well treated and preserved. Their parents involve them in the food storage and preservation practices such as boiling milk, drying fish and salting meat.

Children have traditional/cultural explanations for some of these phenomena. The main question is, does the school science they learn regarding decomposition, food storage and preservation enable them develop acceptable cognitive conceptions? This paper highlights some of the findings with regard to milk preservation and storage.

Sample and Methodology
A total of 998 students were involved in the study. Two instruments were used: questionnaire and interview schedule. Questionnaires were administered to the 998 students at four school levels. The sample size is shown in tables 1 and 2 respectively.

Table 1. Distribution of survey test sample children according to level of schooling, sex and age.

<table>
<thead>
<tr>
<th>Year of schooling</th>
<th>Number of pupils</th>
<th>Mean age</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>209</td>
<td>12</td>
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<tr>
<td>8</td>
<td>199</td>
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<tr>
<td>10</td>
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<td>16</td>
</tr>
<tr>
<td>12</td>
<td>288</td>
<td>19</td>
</tr>
<tr>
<td>Total</td>
<td>988</td>
<td></td>
</tr>
</tbody>
</table>

The sample was distributed in three districts: Nairobi, Bungoma and Kakamega. Some children were interviewed to get details and clear conceptions. A sub-sample of 127 students was interviewed. Their distribution is as shown in table 2.
Table 2. Distribution of interview children by year of schooling, age and district.

<table>
<thead>
<tr>
<th>Year of schooling</th>
<th>Mean age in Years</th>
<th>District</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Nairobi</td>
<td>Bungoma</td>
</tr>
<tr>
<td>5</td>
<td>12</td>
<td>12</td>
<td>9</td>
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<tr>
<td>8</td>
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</tr>
<tr>
<td>12</td>
<td>19</td>
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<td>14</td>
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<tr>
<td>Total</td>
<td></td>
<td>45</td>
<td>43</td>
</tr>
</tbody>
</table>

Findings.

This section reports the findings of children's understanding and conceptions on milk preservation and storage, refrigeration and boiling.

Children's ideas on milk preservation and storage.

The discussion of children's ideas on milk storage and preservation is presented, according to the method of preservation. Children's verbatim responses are reported followed by the identity of the child written as follows: 946.B.19.12. This should be interpreted as follows:

946 - Serial number of the child in the study sample  
B - Boy  
G - Girl  
19 - Age of the child in years  
12 - Year of schooling (5, 8 Primary, 10, 12 Secondary)

1. Refrigeration.

Children were asked why food kept in a refrigerator stays fresh for long. It was found that the majority of children at all levels of schooling were aware that a
refrigerator keeps food fresh for some time. But they had not constructed a model to explain this phenomenon. The farthest some went was to explain that because the refrigerator keeps food cold, it is the coldness that preserves food, but they did not appear to be aware of the underlying scientific reasons.

1. **Coldness.**

It seems some of the incorrect responses given by children originated with the way the teachers taught the topics. The following transcript with child 863.G.12.5 tends to support this, (R = researcher, S = student.)

R Why is it that if you keep meat in a refrigerator it does not get spoiled quickly?

S Because the ice in the refrigerator is cold so if you put meat in the refrigerator water will come from the ice and pours on the meat removing dirt

R What type of dirt is it?

S Such as blood

R Who told you water pours in the refrigerator?

S The teacher taught us so.

Even some secondary school children who had been taught about food storage did not appear to know what a refrigerator does as exemplified by an extract of an interview with student 093.G.18.12 – a form four girl who is 18 years old.

R I wonder how a refrigerator keeps food fresh for a long time.

S Eh, what, I think it is because of, OK, it will be frozen and meat can stay fresh for as long as you like, because of the temperature, thus, *yaami* (because), ahmm, the temperature is the one that will keep it the same because, it wouldn’t be at heat, then kind of expands and contracts, or will just be frozen intact, and it wouldn’t allow any of these, hmm, these worms, it wouldn’t allow any outside parasite but it will be frozen.

2. **Refrigerator does not allow micro-organisms to be formed.**

Some children thought refrigeration does not facilitate the formation of micro-organisms. For example, "The reason for this is that bacteria which makes the meat
to spoil is not formed, i.e. the meat lacks decaying bacteria. Low temperature prevents the formation of bacteria”. (946.B.19.12). The boy thinks the meat lacks decaying bacteria because they have not been formed due to low temperature in the refrigerator. Student 620.B.14.5 held a similar idea on how a refrigerator keeps food fresh as the following part of interview transcript shows.

R Why is it that meat kept in a refrigerator does not get spoiled quickly?
S Because it makes the meat cold.
R Why is it that cold meat does not go bad quickly?
S Because maggots cannot develop in it.
R Why not, I wonder?
S Because it is cold.

Some children thought the refrigerator preserves food by killing micro-organisms. The refrigerator does not kill micro-organisms. In such low temperatures they become less active. It is interesting to note that over 20% of secondary school children who had learnt the biology of micro-organisms, and their role in food storage believed that a refrigerator preserves food by killing the micro-organisms.

2 (a) Boiling milk.
This is a common method of preserving milk in homes. Children were asked why boiled milk lasts longer.
Some children, especially young ones thought that boiling drives out germs from the milk as the following transcript with student 399.B.13.5 illustrates.

R Why is it that boiled milk cannot go bad quickly?
S Because if it has just come from the cow and you boil, the germs will escape.
R Will escape to where?
S When you are boiling it, the germs will go up.
R Can we see the germs going up?
S No.
R Why Not?
S It will be going up in the form of smoke.
By saying ‘smoke’ the child was probably referring to steam that comes off when liquids such as water and milk boil. Some children thought that viruses are involved in the spoilage of milk as student 789.G.16.10 explained “...is boiled, the viruses that make it go bad quickly are destroyed”. It is known that viruses are not involved in milk spoilage. Bacteria do. This means some children cannot differentiate between bacteria and viruses.

(b) Other suggested methods of preserving milk.

Children were asked to explain other methods of preserving milk.

1. Cold water.

Many children at all school levels suggested the milk can be preserved by putting in cold water. This is because this is a method widely used in those homes in Kenya where there are no refrigerators, and so the children appear to be most familiar with it even in kiosks. However, in such everyday practices, the reasons underlying the activity are not commonly talked about. So younger children use their own intuition to suggest that cold water acts as a refrigerator. Meanwhile the older secondary school children use both everyday science and formal science to suggest a range of alternatives and explain them.

Although many children suggested the use of cold water as an alternative method of keeping milk fresh, they had varied explanations as to how cold water facilitates this. For example:

- "...cold water will be acting as a germ destroyer." (157.G.19.12)
- "By keeping it (milk) in a bucket of water, i.e. it should be deeply immersed in water. Because when the bacteria enters they will not find its way to reach the milk so they'll just float on water." (232.G.19.12).
- "Milk can be kept longer if it is kept in a cool wet place, i.e. in water. This makes the milk to remain in the same state as when in the animal" [meaning the cow]. (256.B.20.12).
- "Putting the milk in cold water prevents bacteria because they fear cold places". (284.B.19.12).

Some children appeared to hold and use some science knowledge without understanding it. For instance, in the interview with student 215.G.16.10, when asked to suggest any other method of keeping milk longer, she said:

S   Put it in cold water and cover on the top with a muslin cloth.
R Why?
S This is another method of keeping milk fresh for long.
R Why should you put it in cold water?
S We were just taught that way.

Thus this student appeared to have no idea why the milk should be put in cold water and was unwilling to think beyond the action. It is evident that many teachers do not enable students grasp the underlying scientific concepts.

It is worth noting that whereas most school year 5 and 8 children suggested putting the milk in cold water as the only alternative to refrigeration, secondary school children suggested other options such as pasteurisation, making milk powder and skimmed milk.

2. Pasteurisation.
It is interesting to note that although some children suggested pasteurisation as another method of preserving milk, they appeared to attach different meanings to the process from that accepted by scientists as the following quotations illustrate:

- “Pasteurisation - milk is treated with antibiotics and so it can stay longer”. (184.B.19.12).
- “Pasteurisation; milk is removed the cream and chemicals are added so that it stays longer”. (186.B.19.12).
- “Pasteurisation. The milk is kept in powder form and so no bacteria can exist in that type of milk”. (308.B.19.12).
- “Pasteurisation. A chemical is inserted and kills bacteria”. (476.B.15.10).

Preserving milk in powder form is another method suggested by children. But their reason for converting it into powder form differs from accepted science, as the following example illustrates: “Processing it to powder milk. If milk is converted into powder form, there is no likelihood that the bacteria can infect because already the milk particles are strongly held together such that it can’t allow any foreign body.” (248.B.19.12). This reveals the children’s confused understanding of a scientific principle that in solids the molecules are more strongly held together than
in liquids. Such children did not appear to be aware that bacteria need water to be active and that is why milk powder can last longer than liquid milk.

5. Using a Sieve.

Another method suggested by children for preserving milk is using a sieve as student 790.G.19.10 explained: "Sieving. Sieving helps as one is able to see milk is in good condition by removing any impurities that may have entered the milk". The student referred to the use of a fine sieve which the government public health inspectors instruct farmers to use after milking the cows. This was meant to remove objects such as hair and ticks from the milk. Children appeared to think the sieve would remove micro-organisms as well. Indeed student 807.G.16.10 showed that this was in fact the case when she suggested "Sieving or filtering. It will remove the bacteria that may have dropped in milk which can make milk decompose". Such children may not be aware that bacteria would go through a sieve or an ordinary filter, perhaps not conceptualising the relative sizes of the bacteria and the mesh of the sieve.

Student 800.G.17.10 said "Another method of keeping milk for a long period is by tying a clean table cloth at the top of sufuria [a cooking pot] or any container having milk". Again the public health inspectors, in order to reduce communicable diseases in the country go round villages educating farmers that after milking, the milk should not be left exposed as flies may land on it and infect the milk with germs. Consequently, they are advised to cover milk containers with clean tablecloths because normally the cooking pots do not have lids. It would appear that the children, through their own intuition, believe that such a tablecloth is meant to protect the milk against the microbes. They appeared to be unaware that a clean tablecloth does not mean it is sterile, and therefore may still harbour microbes. An interview with student 304.B.18.12 illustrates this

R  Is there any other method of keeping milk fresh that you can think of?
S  You keep it in cool places. And also you can cover it with, ahh, a clean cloth to prevent bacteria from entering.
Discussion.

Refrigeration.
The results of the refrigeration probe showed that the majority of children in lower levels of schooling were aware that a refrigerator keeps food fresh for sometime. But they had not constructed a model to explain this phenomenon. The farthest some went was to explain that because the refrigerator keeps food cold, it is the coldness that preserves food, but they did not appear to be aware of the underlying reasons. As they progressed through school, more children replaced this naïve conception with a more scientific explanation involving micro-organisms.

From the responses it appears that some children were not aware of what a refrigerator is and how it works. Refrigerators are owned by a relatively small percentage of the Kenyan population, most of who live in large urban centres. Refrigerators are not a basic necessity in Kenya, particularly in rural areas, because nearly every family has one or more cows from which they get fresh milk every morning and evening. Besides fresh meat, vegetables and fruits are easily available in the villages.

It seems some of the incorrect responses given by the children originated with their teachers. Even some secondary school children who had been taught about food storage and preservation did not appear to understand how a refrigerator works. Some children at all school levels thought the refrigerator does not facilitate the formation of micro-organisms. Some children thought the refrigerator preserves food by killing micro-organisms.

The refrigerator does not kill micro-organisms. In low temperature bacterial activities are drastically reduced, but when the temperature becomes favourable, they become active again. Such children may be operating from everyday knowledge, that if organisms such as humans are subjected to low temperatures for a long time they will die. From science knowledge they should be aware that there are some organisms which change their behaviour patterns when environmental conditions such as temperature become adverse, and micro-organisms are among such organisms. It is interesting that over 20% of secondary school children who had learnt the biology of micro-organisms and their role in food spoilage believe that a refrigerator preserves food by killing the micro-organisms.
Boiling milk.
Many children said boiling drives out germs from the milk. Since children are told by their parents and teachers that milk should be boiled to remove germs which might otherwise make them sick, they appear to have intuitively constructed their own idea that the germs must be escaping in the steam which they refer to as smoke.

Some children thought that viruses are involved in the spoilage of milk as student 789.G.16.10 explained "... is boiled, the viruses that make it go bad quickly are destroyed". It is known that viruses are not involved in milk spoilage. Bacteria do. This means some children cannot differentiate between bacteria and viruses.

Implications For Science Teaching And Teacher Education.
This study found that naïve conceptions interfere with children's learning in science. Curriculum developers and science teachers should incorporate and integrate diagnostic classroom tests into the teaching/learning process. This will facilitate effective teaching by the teacher and effective learning on the part of the children (Khatete, 1995, Mehrens and Lehmann, 1984). Such tests should not be confined to paper and pencil alone, because such a test is unlikely to reveal the true nature of the children's naïve conceptions. The teacher should, in addition, use verbal probing questions to ascertain the real naïve conceptions the children hold (Khatete, 1995). The teacher should pose probing questions in groups or whole class discussions during normal teaching/learning discourse.

In the course of teaching and learning of science, children should be enabled to make predictions and explanations, then follow this by "hands-on experiments" to verify or refute their predictions and explanations (Lavoie, 1993). This can be an effective conceptual change leading strategy (Watson & Konice, 1990, cited by Avoie, 1993). Predictions and explanations can be used as instruments to reveal prior knowledge, to motivate, and to establish mental readiness for conceptual change (Cosgrove & Osborne, 1985; Nussbaum & Novick, 1982).

When planning for teaching, teachers should take into account the children's naïve conceptions they bring to the class about the topic being taught, so that they develop strategies that make the process of learning more meaningful, the kind of teaching/learning process that will make the children alter or modify their naïve conceptions
Conclusion.

New trends in science education emphasize that if students are not doing hands-on science, they are not doing science. Simply studying the content of science is not the same as learning science. While knowledge of facts is important, facts must be learned within the context of authentic experience. Science teachers must rethink their traditional role as knowledge deliverer and accept a new responsibility as facilitator and coordinator of experiences. Unfortunately, this approach is the one many teachers, administrators including Education Supervisors, and parents have known and used. Their level of comfort with this model will make it very difficult to change and reform. Science learning requires instructional strategies far different from traditional teaching and learning.

Thinking skills, especially higher order skills, must be learned through hands-on practice. The new paradigm for science learning emphasizes engagement and meaning in ways that are different from traditional practice. Calls for hands-on, minds-on should be authentic. This approach to teaching and learning science enables students to participate fully in the learning process where the teacher is not the only source of knowledge and information. The natural curiosity of children who are eager to understand their surroundings is often dampened by instruction that discourages inquiry and discovery.

A curriculum based on constructivist theory is well suited to the teaching and learning of science. In many African learning institutions science instruction is largely textbook centered. The typical pedagogy in our schools reflects authoritarian, didactic approach to classroom management. Without significant reform in curricula, strategies and methods used in our classrooms, science learning will not improve. Good science teaching model should foster inquiry, acquisition of new knowledge and lifelong learning. Education administrators should be informed about change process that will be needed to create science classrooms that provides active, hands-on, minds-on, authentic learning for students.

From history we know that advances in science have a profound influence on society. They transform lives of people for the better by improving their living conditions.
and productivity of the nation. Reports show that poor ability in science, mathematics and technology certainly hampers Africa's ability to be developing at an appreciable rate relative to developed countries so that she can be able to play a meaningful role in the global village. This state of affairs has made African States to be perpetual 'street beggars' or 'street urchins' in this global village, scavenging in the technological rubbish heap of developed countries. Africa must strive to be an equal inhabitant of this global village rather than resigning herself to third or fourth rate inhabitant. To enable Africa get that status, we should systematically carry out science education reform and innovations, both in content and pedagogy to make it relevant and responsive to her aspirations.

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