Teaching science by constructivist approach as a means of reducing the gap between secondary school students' experiences and the society needs/demands in Tanzania

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Definition of terms:

- *Teaching*: The process of promoting learning to all students. In this case it will be taken as the process of promoting knowledge and skills needed in the society.
- *Constructivist approach*: The teaching and learning approach which insists that the student should learn through the interactions of what they already know and believe and the ideas, events, and activities with which they come in contact.
- *Students' experiences*: The knowledge and skills students attain or acquire after studying in an education system. In Tanzania it includes memorization of facts, algorithmic performances, covering and cramming materials without understanding.
- *Society needs/demands*: The knowledge and skills needed or desired for rapid social and economic development. This helps students after graduation to work in a changing economy and a changing workplace effectively.
- *Science*: A systematic study of anything that can be examined, tested and verified. The study of science as a "way of knowing" and a "way of doing" can help students reach deeper understanding of the world.

Introduction

The essence of teaching is to bring about a change in the behavior, attitude and thinking in the students. The teaching principle a teacher adopts in order to bring about this change matters a lot; this is because students learn most effectively when the learning environment is stimulating and when teaching is lively, interesting and relevant to students' prior knowledge and experience of the world around them. The teaching principle, to be of value, needs the interaction of sensitive teachers to challenge student thinking, exposing them to new ideas. The vision of a teacher using an effective teaching approach is to develop classrooms where students are helped to make sense of, and reflect on, their experiences, assess their work and set future learning goals. In such classrooms students are always encouraged to articulate how they learn; they should be able to express what the problem is that they are working on, what questions and prior ideas they have, and what their plans are to solve the problem. They should know how they are going to evaluate and present their experimental results. Teaching and learning in these classes should be inseparable, in that learning is a criterion and product of effective teaching. In essence, learning is the goal of teaching, that is to say someone has not *taught* unless someone else has *learned* something. So teaching is to try and help someone learn something, or more formally to help someone acquire or change some behavior, i.e. some competencies, attitudes, knowledge and skills, ideas or appreciations (Agbulu & Idu, 2008; Perrot, 1989).

The system of education in Tanzania

The system of education in Tanzania is based on the realization that quality education is the pillar of national development, for it is through education that the nation obtains skilled manpower to serve in various sectors in the economy. The Tanzania system of education has three major levels: Basic, Secondary and Tertiary with the following structures:

- *Pre-Primary Education*: Pre-primary school is a formal school system for children aged between 5 and 6 years. Pre-primary school cycle lasts for 2 years with no examinations for promotion purpose.

- *Primary Education*: Primary Education is a seven-year education cycle after Pre Primary. It is universal and compulsory for all children from the age of 7 years. The primary school cycle begins with standard one (STD I) upon entering, and ends with standard seven (STD VII) in the final year. STD VII examination is a Primary School Leaving Examination (PSLE), marking completion of the primary education cycle, and it is used for selection of students to enter into secondary education.
- *Secondary Education*: The formal secondary school education consists of two sequential cycles:
    - The first cycle is a four year Ordinary Level (O-Level) secondary education (beginning with Form 1 and ending with Form 4).
    - The second cycle is a two year Advanced Level (A-Level) secondary education (beginning with Form 5 and ending with Form 6).

  Form 4 and Form 6 examinations, i.e., CSEE and ACSEE respectively, mark the completion of the secondary education cycles. The results of these examinations are used for selecting students for further higher education and training, and also for certification.
- *Higher Education*: Higher education institutions (universities or tertiary colleges) offer degrees or professional diplomas in different fields of study such as science, business, arts, etc.
- *Teacher Education*: Teachers Colleges offer courses leading to a Certificate in Teacher Education or Diploma in Teacher Education. Minimum admission requirements for Certificate and Diploma courses are Division III of CSEE and ACSEE respectively.
- *Vocational Education*: Vocational education and training prepare, update or retrain artisans for employment or self- employment at the semi-skilled or skilled level in any economic activity. The Vocational Education and Training Authority (VETA) coordinate and harmonize vocational and technical education and training.

To ensure efficiency and effective delivery of education or high standards of education under the decentralized and liberalized education system, there are other agencies in the Ministry of Education and Vocational Education Training (MoEVET) as follows:

- *Planning Department* – to ensure plans, programs, projects and policies are effectively coordinated to improve the quality of education.
- *Inspectorate Department* – Ensures close monitoring of schools as well as horizontal feedback mechanisms between the inspectors and education stakeholders at all levels.
- *Tanzania Institute of Education* – Ensures provision of quality education by designing, developing, implementing, reviewing and updating the curriculum at all levels.
- *National Examination Council of Tanzania* – Ensures national examinations are effectively coordinated (e.g., setting, moderating, supervising, marking and releasing results).

Education for Self-Reliance

In 1967, the government introduced the Education for Self-Reliance (ESR) policy which redefined the purpose of education in the country. According to ESR, the purpose of education was to develop an inquiring mind, the skill to learn from others and to make relevant judgments on what to adopt or adapt, thinking critically and developing confidence and mental liberation. The policy or philosophy of ESR evolved from the philosophy of Socialism and Self-Reliance encompassed in the Arusha Declaration. ESR was designed to review the previous curriculum and the experience of schooling in order to produce children who were more confident, curious, and inquisitive and with critical, liberated minds. Inquiry Science curricula were imported from abroad to achieve these goals. The first curriculum materials brought into the country included the African Primary Science Program (APSP) materials from the US which were adapted to a form called Thinking Science. Others included the Nuffield Science Project adapted throughout East Africa into a form called the School Science Project of East Africa (SSP) and the corresponding School Mathematics Project of East Africa (SMP). These projects were introduced in schools when there was a largely expatriate teacher population from the US, UK and other Western countries since indigenous teachers were insufficient to run the expanded secondary school sector. The situation was similar throughout the East African countries of Tanzania, Kenya and Uganda (Osaki, 2006).

A corresponding teacher preparation program was designed and operated from 1968, funded by the United Nations Educational, Scientific and Cultural Organization (UNESCO), to produce a large number of science and mathematics teachers for the school system to replace leaving expatriates and equip new schools. There was also an in-service component designed to help teachers adapt the Nuffield and other imported materials to the local situation. The SSP, SMP and APSP continued to run until the first cohort completed the cycle. For the junior secondary schools, it was the first group to sit for the 1970 Ordinary level Cambridge Overseas Examination in Biology, Chemistry, Physics and Mathematics. For various reasons the SSP, SMP, and APSP were discontinued after only the first trial, although the spirit of the materials was somehow reflected in later developed textbooks. Among the reasons for discontinuation of the materials included lack of enough trained teachers to teach by inquiry approach and also lack of sufficient equipment for the experimental approach of the SSP, SMP, and APSP in the expanding school system.

Tanzania continued to develop its own science and mathematics teaching and learning materials through the Tanzania Institute of Education (TIE), which from 1973 were examined by the National Examinations Council of Tanzania, NECTA (after breaking from the Cambridge Overseas Examinations System). However, a survey conducted by Chonjo, Osaki, Possi and Mrutu (1996) found that few teachers used inquiry or did experiments; classes were large, gender awareness among teachers was low, and a Unified Science Project started in the early 1990s had become unpopular. Experimental design skills among teachers had deteriorated, as well as use of the local context in lesson presentation. The Tanzania Institute of Education then abandoned the emphasis on inquiry science and continued to write textbooks that focused more on remembering facts and formulae instead of experimental work (Knamiller, Osaki, & Kuonga, 1995; Osaki, 2006).

Research on the state of science teaching and students experiences in secondary schools Tanzania

The teaching and learning of science in Tanzanian classrooms is characterized by the chalk-and-talk methods; practical activities and demonstrations were hardly done at all. Implementation conditions in schools were problematic; students' attitude towards learning focused on memorization. The understanding and application of concepts and theories were not included in their study routines; the science curriculum did not prepare them sufficiently for another approach. The chalk-and-talk approach is characterized by heavy teacher talk and passive students who are either listening to the teacher or copying notes from the board. It requires students to listen to topics, memorize facts, and restate them for evaluation purposes. Knowledge and skills are not duplicated but instead are taught sequentially over time, and teachers often pay little attention to whether or not students use the information in any real-life context. It often does not provide students with opportunities to develop the kinds of critical thinking skills and problem-solving abilities that are central to thinking and learning in science (Chonjo et al., 1996).

Subsequent studies on science and mathematics education (De Feiter, Vonk, & Van den Akker, 1995; Osaki, Ottevanger, & Van den Akker, 2002; Ottevanger, 2001; Van den Akker, 1998; Weiss, Banilower, McMahon, & Smith, 2001) revealed that African classrooms have been typified as dominated by teachers, silent students, and chalk-and-talk as the preferred teaching style and the absence of practical work. Most teachers used transmission rather than interactive pedagogy. They were seen to be authoritarian, dogmatic and inflexible, which is uncharacteristic of the nature of science teaching. Studies noted further that despite the reported emphasis on science process and inquiry skills, classes at all levels are much less likely to stress having students learn to explain ideas in science or learn to evaluate arguments based on scientific evidence. Science student culture is such that students merely memorize, or haphazardly memorize materials without really thinking about or trying to make sense out of it. Students could talk about the material in vague and general terms, and could repeat the examples and statements they were given, but they had no real understanding of the problems. Similarly, when students study science in school they learn the material so they can answer test questions, then move on without worrying whether it really made any sense to them or not. These methods are the predominant teaching format in Tanzanian secondary schools as it is in most Sub-Saharan countries.

Kitta (2004) revealed that the performance in mathematics among ordinary level (O-Level) secondary school students in Tanzania was generally poor. One reason given was teachers' low competence in teaching due to substantial deficiencies in pedagogical content knowledge and skills. Traditional teaching methods are still preferred by some teachers, despite being reported to contribute to problems in student understanding of introductory physics. Having been taught passively for a long time, students are usually resistant to changes in teaching methods (Cahyadi, 2004). Furthermore, Teacher Education Assistance in Mathematics and Science (TEAMS) project researchers reiterate science teaching problems, but some research shows that change is possible although it requires more work and government support. Jokolo (2004) shows that classroom practice in biology still discourages girls due to lack of practical hands-on learning, but suggests some simple tasks which can motivate girls to enjoy learning about science. Kibga (2004) reiterates the problem of an experimental approach in physics classrooms and suggests ways of raising interest in practical work, while Maro (2004) shows that there is failure to relate academic science content with pedagogical training in the current teacher education curriculum in teachers colleges. Mtaita (2004) shows that by using the five E's learning model (Explore, Explain, Elaborate, Evaluate, Engage) it is possible to promote a more practical and stimulating approach in chemistry.

Experience has shown that despite changes to modernize the teaching and learning approaches of science subjects and even after Tanzania had put great emphasis on science-based subjects for the benefit of future development of the country, educators are astonished to learn that despite their best efforts, science students do not grasp fundamental science ideas/concepts covered in classes. Even some of the best students during the lesson give the right answers but are only using correctly memorized words; when questioned more closely, such students reveal their failure to understand fully the underlying science ideas/concepts. Amazingly, rote-learning techniques are still prevalent in secondary schools (Ishemo, 2006). Some studies found that discussion as a participatory teaching method can facilitate learner participation in the learning process, but the way teachers interpret it into classroom practice reveals that there is confusion of what it is and how they can use it to enhance learner participation. In addition there are variations and similarities in teachers' views on what participatory teaching methods are, and the reasons for their use (Barrett, 2007; Kimaryo, 2009; Omari, 2008).

In his presentation on whether or not classrooms are really learner-centered, Townend (researcher from the UK) says many students have little or no experience using their thinking to construct knowledge. He says students are oriented to rely entirely upon their teachers instead of attempting on their own to construct knowledge. This causes some subjects, science in particular, to be considered difficult. Commenting further on Tanzania's education system and teaching methods, Townend says things are different from what he expected to see. He adds that many teachers begin a new topic by asking students what they already know; however at the end of a lecture a teacher asks students if they remember what he/she taught them. No chance is given for students to construct their own knowledge, think for themselves and encourage them to become independent learners ("Needed: Learner-Centered Syllabuses," 2009).

Recently, education sector stakeholders have called on the government to see the need to arrest the rising incidence of students doing poorly in science subjects, warning that failure to take immediate action would make Tanzania run dangerously short of scientists. Most people interviewed expressed unease and surprise at the worsening trend of mass failures in science subjects in the last 10 or so years. They said the nature and level of the country's social, cultural, political and economic development will largely be decided by the contribution of scientists and experts in all other areas of specialization. Dr Matheo Raphael, director of the Centre for Development and Transfer of Technology at the Tanzania Commission for Science and Technology (COSTECH), said the chronically poor performance by students in science subjects was evidence that it would not be long before the nation faced a crisis resulting from a scarcity of experts. "What this means is that we will one day find ourselves with even fewer doctors, engineers, geologists, extension officers and other experts than is currently the case." He explained further that the major explanation of the problem was the ever escalating shortage of science teachers, having too many students in classrooms than is recommended by education experts and lack of well-equipped science laboratories. "If the government really wants to reverse the tide, it must draw up and implement a strategy deliberately aimed at churning out dedicated and competent science teachers, improving school and college laboratories and giving special incentives to science teachers plus in-service training" ("Government Advised," 2010).

Research conducted by NGO's in 2007 at six regions in Tanzania discovered that not a single community secondary school had a science laboratory. "What kind of science experts would anyone expect to see emerging from such secondary schools?" queried researchers, calling on the government to direct more funding and other resources into priority issues such as regularly upgrading training for teachers "to help them acquire new teaching methodologies and techniques." They urged education stakeholders to address the mass failures in science subjects by deploying new teaching and learning methods. They said the methods currently in use do not encourage innovation "which students need to perform better," prescribing innovative learning as "a more proper method sure to help students think and learn skills rather than merely cramming" ("Government Advised," 2010).

There were various efforts to address science problems and how the situation could be improved in different ways and levels, for example the Science Education in Secondary Schools (SESS) project whose goal is to equip deprived schools with textbooks and teaching apparatus as well as run in-service education programs for science teachers. Another project is the Science Teaching Innovation Program (STIP) project whose provision is to provide up-to-date textbooks to church schools in Tanzania, and to rehabilitate laboratories and equip them with a basic set of chemicals including science equipment. At the University of Dar-es-Salaam (USDM), the TEAMS project was established as a response to a study which showed the poor state of science and mathematics in the country. TEAMS is a cooperative effort between science and mathematics educators at UDSM and Dutch counterparts aimed at assisting with the production of more and better-qualified science and mathematics teachers. Specifically the project has a mission to improve teaching of science and mathematics in secondary schools. Obviously, this project has brought many hopes for a learner-centered approach in science and mathematics teaching in Tanzania (Ottevanger, Feiter, Osaki, & Van den Akker, 2005).

A curriculum review conducted by the Tanzania Institute of Education (TIE, 2009) on the status of curriculum for secondary schools showed that the majority of school graduates lack many crucial competencies including proficiency in spoken and written English, entrepreneurial skills, social life skills, creativity, self-confidence, numeracy, patriotism and ICT mastery/application. It can be said that there is a gap between science student experiences and the society needs/demands. So it seems that the dominant experiences science students encounter during teaching and learning (experienced curriculum) are generally those of the traditional methods. These methods have a subject-centered orientation which has the following characteristics:

- Students gain mastery of subject matter predetermined by a set of educators
- Overemphasises on verbal answers, reliance on rote memorization
- Students focus on memorizing what they are told, and one correct answer is sought

- Students are the receivers of information, and the teacher is the dispenser
- More concern with preparation for the next grade level and in-school success than with helping students become lifelong learners
- At its most extreme, it omits the importance of learner experience, requiring a learner to accept, rather than challenge, the information being transmitted

Students graduating in tradition-based education lack crucial knowledge, skills and competences needed for socioeconomic development (Educational Broadcasting Corporation, 2004; Nyagura, 1996).

Societal needs/demands

The oldest method of meeting societal needs/demands was for the parents to pass on to their children the occupational information they had acquired from their parents, as well as what they had learned by trial and error during the generation of productive work. Under this method many developing countries faced the problem of workers who lack knowledge/skills/competencies; as a result many societies failed to have people who could meet the manpower needs and societal demands. Due to changes in manpower and societal needs the transmission of family heritage was no longer a satisfactory educational program for workers in the newly generated occupations. Others found schools to be the right places for students to learn and acquire knowledge and skills which could help them cope with society. However, it was found that the dominant experiences science students encounter during teaching and learning were still not appropriate in terms of the knowledge and skills needed in society. The demands of society are aimed at students who possess knowledge and skills needed for rapid social and economic development and also that will enable them to function in a changing economy and a changing workplace (Evans, 1971; Murcia, 2005).

Our society apparently needs more and more “polyvalent” individuals, capable of multiple adjustments, with a vast range, and capable of successive accommodations and re-accommodations, in accordance with social demands. Our society needs graduates who can be competent in different fields like technology, entrepreneurship, language, globalization, teamwork, human rights, good governance, life skills, networking, etc. So in a context of increasing globalization, millennium development goals and new challenges posed by new changes in the societies, schools and colleges should re-evaluate their programs and strategies. School and college graduates can play a dynamic role in engineering the technological and economic visions of their society. It seems that society has lost its confidence on school and college outcomes, and due to this fact, the view that schools and colleges should target pursuit of knowledge/skills for its own sake has lost much of its appeal. The global advance of information technologies and economic reasons compel us to seek a new role for schools and colleges (Ilisoi, Naggy, & Constantinescu, 1999).

The need for reform

Due to the existing gap between science students' experiences gained from the school and the societal needs/demands, there is a need for reform. To help ensure that reform does happen, continuing community support for science education is essential. Such support is not easy to sustain in the face of changing demographics and changing social priorities. Therefore, informed and determined political leadership at every level and in every sector (government, business, labor, and education) is crucial for achieving reform. Without such leadership, community support for educational reform will fade away long before lasting results can be achieved. The reforms in science education are necessary to improve and enhance science teaching and learning for all students (American Association for the Advancement of Science, 2006; National Council of Teachers of Mathematics, 1991).

Although creative ideas for reforming education come from many sources, only teachers can provide the insights that emerge from intensive, direct experience in the classroom itself. They bring to the task of reform a knowledge of students, craft, and school culture that others cannot. Moreover, reform cannot be imposed on teachers from the top down or the outside in. If teachers are not convinced of the merits of proposed changes, they are unlikely to implement them energetically. In either case, the more teachers share in shaping reform measures, and the more help they are given in implementing agreed-upon changes, the greater the probability that they will be able to make those improvements stick. Although teachers are central to reform, they cannot be held solely responsible for achieving it. They need allies. Thus, school administrators, education policymakers and educators who are experts on relevant subject matter, child development and learning and the educational potential of modern technologies need to support teachers. They need help and support of community leaders, business/labor leaders and parents, for in the final analysis, educational reform is a shared responsibility. During the reform science teachers/educators need to put into practice the following:

- Students must be actively engaged in constructing their own understanding of science, technology, and the world in which they live. We need to create more opportunities for students to engage in science learning that is authentic and patterned after the methods that scientists use.
- By practicing good habits of research, students will systematically learn the process skills needed to participate in meaningful scientific investigation of natural phenomena.
- Teachers must use a variety of alternative assessment tools to allow students to demonstrate their understanding of science by solving authentic, real-life problems.
- Students must develop the skills needed to seek information, construct new knowledge and solve problems.
- Thinking skills, especially higher-order skills, must be learned through practice.
- Teachers need professional development programs which will enable them to change instructional strategies and adapt them to new methods for teaching.
- A thorough understanding and application of the constructivist approach to teaching and learning should be part of the science education program, and “hands-on, minds-on, authentic science” should be the goal of most science education reform.

Constructivist approach

Vygotsky and cohort theorists Piaget, Bruner, Dewey and Kelly fall under the paradigm of constructivism. This is the major instructional practice which has emerged over the last two decades; it is sometimes termed the constructivist model of learning. A constructivist model of learning assumes the existence of learners' conceptual schemata and the active application of these in responding to, and making sense of, new situations. Perhaps most basic is the idea that learning is an active process within which learners are constantly constructing thought which always springs from their own experience and structures of thought. Constructivism is intensely learner-centered; what learners know, what they need to know next and how they might begin to understand and assimilate such new knowledge is the focus of the constructivist design. It is a theory of learning based on the principle that learners construct meaning from what they experience. It sees learning as a dynamic and social process in which learners actively construct meaning from their experiences in connection with their prior understandings and the social setting, thus learning is an active, meaning-making process. Students construct their own knowledge base using old constructs in new situations and adapting them to fit newly learned information (Driver, Leach, Miller, & Scott, 1996; Vygotsky, 1978).

The constructivist approach to teaching and learning calls for learning that is:

- **Hands-On**: Students are actually allowed to perform science as they construct knowledge, meaning and acquire understanding. Students are encouraged to manipulate their environments or a particular learning tool (e.g., experimentation, group work to solve problems).
- **Minds-On**: Activities focus on core concepts, allowing students to develop thinking processes and encouraging them to question and seek answers that enhance their knowledge and thereby acquire an understanding of the physical universe in which they live.

- **Authentic**: Students are presented with problem-solving activities that incorporate authentic, real-life questions and issues in a format that encourages collaborative effort, dialogue with informed expert sources, and generalization to broader ideas and application.

This approach enables students to participate fully in a learning community where the teacher is not the only source of knowledge and information. It encourages full involvement in a community of learners that includes other students, parents, teachers and outside experts. Technology becomes a tool supporting the learning process as students seek new knowledge and understanding. In this framework students learn science by doing concrete scientific investigations (Christensen, 1995; Linn, 1998).

Use of the constructivist approach in teaching and learning science in Tanzania needs to become a common agenda in science education as efforts of shifting from traditional methods (teacher centered) to modern methods (learner centered) of teaching and learning are made. Learner-centered teaching goes hand in hand with constructivism which maintains that the learner should learn through his/her activities. Some of the qualities of learner-centered teaching are (Eastern Inspectorate Zone, 2009):

- the learner learns by doing a variety of logical and planned activities
- the lesson is built on what the learner already knows (past experiences are respected)
- the learner seeks knowledge by interacting with the teacher, the peer, the teaching and learning materials and the subject matter content
- teaching and assessing is done by covering all 6 levels of the cognitive domain
- the teacher is a facilitator of learning rather than a provider of knowledge

One could conclude that the constructivist model of learning is proving to be very useful in helping students understand science better.

Learner-centered learning is premised in the constructivist epistemology of learning which advocates the promotion of more learner-centered l classroom activities (Jonassen, 1991). With constructivism, learning is founded on the premise that “we are able to construct our knowledge and understanding of the world, through experiencing things and reflecting on those experiences" (Smith & Ragan, 1999, p. 15). That is, when we encounter new experiences, we have to reconcile them with our previous ideas and experiences. This may result in changing what we believe, or maybe in discarding the new information as irrelevant. Regardless of which action we take, we are active creators of our own knowledge. When we construct our own knowledge we are learning. This is achievable through mental activities that enable us to generate our own rules and mental models which we can use to make sense of our experiences. Learning, therefore, becomes the process of adjusting these mental models to accommodate new experiences. That is, learning is a search for meaning. Therefore, learning must start with the issues around which students are actively trying to construct meaning. To do this, we must ask questions, explore, and assess what we know. This construction of knowledge is developed from previous knowledge.

Smith and Ragan (1999) highlight some key assumptions of constructivism that may have implications for instructional design and development for educational purposes. These include:

- Knowledge is constructed from experience.
- Learning results from a personal interpretation of knowledge.
- Learning is an active process in which meaning is developed on the basis of experience.
- Learning is collaborative, with meaning negotiated from multiple perspectives.
- Learning should occur (or be "situated") in realistic settings.
- Learning is interactive, building on what the student already knows. The purpose of learning is for an individual to construct his or her own meaning, not just to memorize the "right" answers and regurgitate someone else's meaning.
- Teaching and learning materials include primary sources of material and manipulative materials.
- Teachers have a dialogue with students, helping students construct their own knowledge.
- Testing should be integrated into the task, not a separate activity.

One of the objectives of teaching science subjects in Tanzania is to provide opportunities for the acquisition of knowledge, skills, attitudes, abilities and understanding in prescribed or selected fields of study. The constructivist approach during teaching and learning is an area of much current interest; this is because it is more appropriate for developing effectively the competencies stated by the Tanzania Institute of Education (TIE) for students to acquire in order to solve social, economic and scientific problems. Thus, the system of education should respond to the reform movement in science education and sensitize awareness in order to modernize teaching and learning processes which could finally translate into everyday classroom instructional methods (United Republic of Tanzania, 2007).

The principles that provide the essence of constructivist pedagogy are: emphasizing the student's role in knowledge and skill acquisition through experience, puzzlement, reflection, and construction. Pedagogy is based on the dynamic interplay of mind and culture, knowledge (content and skill), meaning, reality and experience. The general theoretical and practical constructivist consensus indicates that these principles are essential in constructivist pedagogy (Brooks & Brooks, 1999; Doolittle & Camp, 1999; Larochelle, Bednarz & Garrison, 1998) These principles are appropriate to employ during the curriculum implementation processes because they put more emphasis on learner-centered classroom practices which currently could be taken as quality teaching and learning for solving problems in Tanzanian secondary science education.

a) Learning should take place in authentic and real-world environments

Whether building accurate representations of reality, consensual meanings in social activities, or personally coherent models of reality, experience is paramount. Experience, both socially oriented and object oriented, is a primary catalyst of knowledge and meaning construction. Experience provides the activity upon which the mind operates. In addition, knowledge construction is enhanced when the experience is authentic. For the cognitive constructivist, authentic experiences are essential; so the individual can construct an accurate representation of the "real" world, not a contrived world.

b) Learning should involve social negotiation and mediation

While only social constructivism emphasizes social interaction as a basis for knowledge construction, cognitive and radical constructivisms do assign social interaction a role. Social interaction provides for the development of socially relevant skills and knowledge, as well as providing a mechanism for perturbations that may require individual adaptation. In some cases, such as cultural mores and culturally arbitrary rituals (e.g., greetings, gender relations, dress), knowledge can only be attained through social contact. In addition, as an individual gains experience in a social situation, this experience may verify an individual's knowledge structures, or it may contradict those structures. If there is contradiction or confusion, then the individual must accommodate this contradiction in order to maintain either an accurate model of reality or a coherent personal or social model of reality. Finally, an integral component of social mediation is the use of language. Language is the medium through which knowledge and understanding are constructed in social situations (Spivey, 1997).

c) Content and skills should be made relevant to the learner

Constructivism generally emphasizes the concept that knowledge serves an adaptive function. If knowledge is to enhance one's adaptation and functioning, then the knowledge attained (i.e., content and skills) must be relevant to the individual's current situation, understanding, and goal. This relevancy is likely to lead to an increase in motivation (Pintrich & Schunk, 1996) as the individual comes to understand the need for certain knowledge. Ultimately, experience with relevant tasks will provide the individual with the mental processes, social information, and personal experiences necessary for enhanced functioning within one's practical environment. In agricultural education, for instance, a problem-solving approach to teaching has long emphasized the importance of personal relevance in learning (Hammonds & Lamar, 1968).

d) Content and skills should be understood within the framework of the learner's prior knowledge

All learning begins within an individual's prior knowledge, regardless of constructivist affiliation. Understanding a student's behavior requires an understanding of the student's mental structures, that is, an understanding of the student understanding. When a student replies that the answer to 54 - 38 is 24, the teacher must not think "Oh, that is wrong," but rather "What is the student's understanding of subtraction that has led to this answer?" In this case, the student appears to be using the following rule of subtraction, "subtract the smallest from the largest." While this rule is "incorrect" given our current system of mathematics, it is, nonetheless, the rule the student is using. Understanding the student's rule usage makes it much easier for the teacher to demonstrate, using manipulatives of some type, the non-viability of the student's understanding (e.g., have the student count out 54 blocks, then take away 38 blocks from that pile, and finally count the remaining 16). Only by attempting to understand a student's prior knowledge will the teacher be able to create effective experiences, resulting in maximal learning.

e) Students should be assessed formatively, serving to inform future learning experiences

Constructivism asserts that the acquisition of knowledge and understanding is an ongoing process that is heavily influenced by a student's prior knowledge. Unfortunately, knowledge and understanding are not directly visible, but rather must be inferred from action. Thus, to take into account an individual's current level of understanding in this ongoing teaching and learning process, a teacher must continually assess the individual knowledge. This formative assessment is necessary to accurately create the next series of experiences and activities for students.

f) Students should be encouraged to become self-regulatory, self-mediated, and self-aware

The underlying tenet of constructivism, and the main thread that holds together this array of theoretical positions, is the claim that learners are active in their construction of knowledge and meaning. This activity involves mental manipulation and self-organization of experience, and requires that students regulate their own cognitive functions, mediate new meanings from existing knowledge, and form an awareness of current knowledge structures. Within a cognitive constructivist perspective, self-regulation, self-mediation, and self-awareness would be subsumed under the construct of metacognition. Metacognition is considered an essential aspect of learning and consists of (a) knowledge of cognition (i.e., knowing what one knows, knowing what one is capable of doing, and knowing what to do and when to do it) and (b) regulation of cognition (i.e., the on-going task of planning, monitoring, and evaluating one's own learning and cognition) (Brown & Palincsar, 1987).

g) Teachers/instructors serve primarily as guides and facilitators of learning

In actuality, in the cognitive constructivist perspective, the role of the teacher is to create experiences for student participation that will lead to appropriate processing and knowledge acquisition. Consequently, cognitive constructivism supports the teacher as a guider or facilitator to the extent that the teacher is guiding or facilitating relevant processing. The teacher-as-guide metaphor indicates that the teacher is to motivate, provide examples, discuss, facilitate, support, and challenge, but not to attempt to act as a knowledge conduit. The role of teacher as guide was described by von Glasersfeld, (1996), "From this point of view, then, the task of the educator is not to dispense knowledge but to provide students with opportunities and incentives to build it up" (p. 7).

h) Teachers should provide for and encourage multiple perspectives and representations of content

The relationship of multiple perspectives and multiple representations is one of cause and effect within cognitive constructivism. Experiencing multiple perspectives of a particular event provides the student with the raw materials necessary to develop multiple representations. These multiple representations provide students with various routes from which to retrieve knowledge and the ability to develop more complex schemas relevant to the experience. This being the case, a student's understanding and adaptability is increased when he or she is able to examine an experience from multiple perspectives. In almost all settings, there is more than one solution to any problem, more than one way to accomplish any task. A fundamental assumption of inquiry-based instruction is that multiple solutions to any problem are possible (Hammonds & Lamar, 1968).

Conclusion

This paper explained, adopted and suggested the use of a constructivist approach during teaching and learning in order to fill the gap between science students' experiences and societal demands, the ultimate goal being to improve teaching and learning of science in secondary schools in Tanzania. The forum organised by Oxfam GB played an important role in allowing all relevant players to improve their understanding and knowledge of learner-centered innovations in Tanzania through sharing of best practices. The emphasis is on training and capacity building in teachers so that they can impart quality education to their students, and also to press for its effective adoption in all science classrooms in the country. We know in any education system the quality of the teaching force is an indication of the quality of education in that system. A well-educated science teacher must develop an understanding of how different students learn, who can help individual students learn and assess when that learning has taken place.

The conclusion drawn in this paper asserts that the constructivist approach introduced via carefully designed curriculum materials has the potential for improving teaching and learning practices which make science classes more interactive, interesting, and enjoyable. It also allows students to carry out many practices for themselves, collaborate with peers, and communicate with their teachers freely. There is a need to promote Tanzania's system of education so that it can be guided by a constructivist approach for the purposes of meeting the needs/demands of society. Stakeholders can understand the importance and desirable outcome of science schooling especially its fundamental role in helping students to solve problems effectively. One of the most significant factors in improving the quality of teaching and learning by a constructivist approach is the teacher. Thus, it is recommended that educational jurisdictions provide teachers with support of ongoing professional development to help them teach science in ways that promote the constructivist approach to improve learning outcomes.

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