Science Teachers' Beliefs and the Epistemological Underpinnings of the Science Curriculum for Secondary Education in Tanzania

Albert Paulo Tarmo
University of Dar es Salaam, School of Education
Department of Educational Psychology and Curriculum Studies
Dar es Salaam, Tanzania
E-mail: palbert@udsm.ac.tz

Abstract

This study intended to establish why science teachers in Tanzania are quick in discarding learner-centred pedagogic practices in favour of the default transmissive teaching. The study explored science teachers' beliefs about knowledge and analysed science curriculum to establish its' epistemological underpinnings. Afterward, the study compared science teachers' beliefs with the epistemological foundations of the curriculum to establish the (in) congruity between the two. It was found that science teachers held beliefs about scientific knowledge that largely contrast the assumptions about knowledge that underlie secondary science curriculum in Tanzania. It was concluded that science teachers in Tanzania could be resisting pedagogical change partly because the basic assumptions about scientific knowledge associated with learner-centred pedagogy as reflected in the curriculum are inconsistent with those they hold.

Keywords: *pedagogy, learner-centred pedagogy, epistemic belief, nature of science.*

Introduction

In recent decades, there have been enormous efforts to promote learner-centred pedagogy to improve the quality of teaching and learning in Sub-Saharan African (SSA) schools (Akyeampong, 2017). Underlying such reform initiative is the assumption that when teachers receive pedagogical training and swing from teacher-dominated transmissive teaching to interactive learner-centred pedagogies, improved quality of learning outcomes can be achieved (Guthrie, 2016).

Like other developing countries, Tanzania has been constantly undergoing reforms in teaching, particularly in science education (Ministry of Education and Vocational

Training (MoEVT), 2013). Notably, efforts to reform teaching focus on replacing teacher-fronted teaching characterised by teacher-led explanation, recitation, cued elicitations, and choral answers with learner-centred interactive teaching that promote creativity, critical thinking and problem solving (Hardman et al., 2015; Semali & Mehta, 2012; Vavrus, 2009).

In the mid-1990s, the then Ministry of Education and Culture (MoEC) collaborated with public universities to promote learner-centred pedagogy through donor funded massive science teacher professional development programmes (Osaki, 2007). Most notable programmes include Science Education in Secondary Schools (SESS), Science Teacher Improvement Projects, Teacher Education Assistance in Mathematics and Science (TEAMS) and Education II Project (Osaki, 2007).

In the late 1990s, learner-centred pedagogy gained a formal policy attention when the government formulated master plans for basic, secondary and teacher education. The policy advocated, among other things, review of primary, secondary and teacher education curricula to adopt learner-centred pedagogy (Vavrus & Bartlett, 2012). The revised curricula present learner-centred pedagogy as an approach that gives primacy to learners during planning and teaching (MoEVT, 2013). It, for example, states that 'the implementation [of the curriculum] shall emphasise [a] learner-centered approach… the learner shall be placed at the focus of all the decisions that are made about the curriculum and how it will be delivered' (MoEVT, 2013, p.29). It further appeals to constructivists' theory of knowledge by stating that 'learning shall be rooted in the conception of constructivism where the student gets opportunities to interact with [the] environment through well-organized tasks, dialogue, and reflections… and eventually arriving at agreed solutions' (p. 29). Most importantly, the teacher and the learner are expected to be active participants in co-constructing knowledge with their roles being stipulated as follows:

> The teacher shall become [a] facilitator, motivator and a promoter of learning during the classroom interactions. Teachers shall be required to plan and design relevant tasks that will let students question, critically think, form new ideas, create artifacts and therefore bring sense in the learning process (MoEVT, 2013, p. 29)

The government made enormous efforts to promote learner-centred pedagogy, yet lack of sustained success in shifting the teaching paradigm is widely acknowledged in science education (Semali, Hristova & Owiny, 2015; Semali & Mehta, 2012; Tarmo, 2016). Literature shows that the default model of teachers teaching using transmissive techniques and learners learning through rote, recitation, and copying notes continue to dominate science lessons in Tanzania (Semali & Mehta, 2012).

However, the explanation for the resilience of the traditional model of teaching remains disputed (Guthrie, 2016). Teacher training, under-resourced large class sizes and misaligned pedagogy, curriculum and examinations are often recognised to render learner-centred pedagogy unfit for the Tanzanian classroom contexts (Semali et al., 2015; Vavrus & Bartlett, 2012). Consequently, the government has allocated resources to tackle such structural constraints by expanding school infrastructures, supplying materials and providing continuous teacher professional development. Yet, the lack of sustained adoption of learner-centred innovation is widely acknowledged and transmissive science teaching predominates (Tarmo, 2016).

In Tanzania, what has received little research and policy attention; however, are the teachers' beliefs about what constitutes scientific knowledge and how they should teach. Research shows that when teachers hold beliefs that conflict with the vision of promoting learner-centred pedagogy through innovative curriculum, teachers are likely to reject or superficially implement reform proposals in ways that fit their beliefs (Fives & Buehl, 2016; Glackin, 2016).

Further, while the curriculum that promotes learner-centred pedagogy is founded on specific epistemological assumptions, its implementation in the classroom involves teachers and students who have deeply held views about knowledge and teaching shaped by cultural and educational backgrounds (Bruner, 1996; Fives & Buehl, 2016). For example, the principle that knowledge should be co-constructed between a teacher and students that underpins the curriculum may conflict or undermine the authority vested upon teachers as knowledge authorities in the context of Tanzania (Hamminga, 2005). Often in this context, adults are assumed to possess uncontested knowledge due to their longer life experiences (Kresse, 2009). Consequently, the curriculum principles that demand teachers to encourage students to interrogate authoritative knowledge sources may be rejected on the grounds of being contradictory to the basic cultural beliefs.

In explaining the Tanzanian science teachers' resistance to adopt learner-centred pedagogy in their classrooms, this investigation presents findings and the conceptual approach of a study that explored science teachers' beliefs about scientific knowledge and how these compares with the basic assumptions about knowledge that underpins science curriculum for secondary education in Tanzania.

Teachers' beliefs: An overview

The ideas, thoughts, and assumptions underlying teachers' practices are often termed as teachers' beliefs or conceptions. The concept teachers' beliefs refer to teachers' implicit assumptions about learners, learning, classrooms and the subject matter' (Kagan, 1992). In the context of science teacher education, science teacher's belief is conceptualised as a mental representation that influences the practice of a teacher when the belief is active in the cognition (Hutner & Markman, 2016).

Beliefs form a complex interconnected network of person's cognitive structure. While some beliefs are core, others are peripheral thus, the chances of teacher's belief change vary along the core-periphery dimensions with core beliefs being more difficult to alter (Hutner & Markman, 2016). In addition, teachers are likely to hold on and enact the core beliefs that they assimilated earliest into their schemata even when they are aware that such beliefs are based on false or partial knowledge (Hutner & Markman, 2017). Most importantly, teachers often tend to reinterpret contrasting evidence in ways that support their pre-existing beliefs thereby contributing to belief robustness.

In the context of teaching, teacher beliefs about knowledge, teaching and learning are the most salient because the content and how teachers teach are most logical and useful in accomplishing the teaching task (Hutner & Markman, 2017). This study focused on epistemological beliefs, which are beliefs about the subject matter of science (Hofer, 2001).

Science teachers' epistemological beliefs

Epistemological beliefs constitute ideas that individuals hold about knowledge and knowing. Such ideas consist of what counts as knowledge, how it is created and evaluated, where it resides and how knowing occurs (Hofer, 2001). Epistemological beliefs have been theorised differently. Most prominently, however, it is presented by the Systemic Model (Schommer, 1990) in which epistemological beliefs are theorised as a system of more-or-less independent beliefs that fall on the continuum of 'naïve' to 'sophisticated' beliefs basing on the dimensions of the source, structure, stability, speed and the ability to know (see Table 1).

Table 1: *Categories of Beliefs about Knowledge*

Dimension	Naïve belief	Sophisticated belief
Structure	Fragmented bits of concepts	An integrated set of concepts
Stability	Unchanging/certain	Ever changing/uncertain
Source	Authority/expert	Evidence and reasoning
Speed of knowing	Quickly or none	Gradual
Ability to know	Fixed at birth	Improvable with time/experience/effort

For Schommer, individuals who hold naïve belief see knowledge as simple, certain and steady facts that omniscient authorities hand down. They believe the ability to know is innate thus knowing occurs either quickly or not at all. In contrast, those who hold sophisticated belief see knowledge to be uncertain and tentative interrelated concepts progressively created and recreated based on reasoning and evidence (Schommer, 1990). To cover the range of epistemological beliefs that teachers can potentially possess, Schommer's model was adopted, especially her recent concept of the balanced magnitude of epistemological sophistication instead of extreme dualism or relativism (Schommer-Aikins, 2004).

The influence of epistemological beliefs on the envisioned curriculum

Researchers generally acknowledge the value of considering teachers' beliefs when attempting to reform their pedagogic practices (Fives & Buehl, 2016; Levin, 2015). This serves educators from prematurely proclaiming the successful teaching reforms without carefully scrutinising teachers' belief systems for close congruency with the fundamental principles of the reforms.

Teachers' beliefs influence the perception, understanding, and implementation of the basic principles underlying the curriculum innovation (van Driel, Bulte & Verloop, 2005). When the envisaged curriculum reforms contradict their beliefs, teachers often alter the proposed changes to fit their belief structures or ignore aspects of the reforms that conflict their beliefs (Bryan, 2012). This means they distort the envisioned reforms through the old frameworks of practice (Glackin, 2016).

The impact of teachers' beliefs on the principles and ideals of the innovative curricula is well illustrated by Park, Hewson, Lemberger and Marion (2010). Park et al. (2010) reported about prospective teachers who modified the objectives of the conceptual change curriculum to fit their pre-existing epistemological beliefs. These teachers were reluctant to encourage their students to interrogate textbook knowledge because they accorded it a high status. Some of the participants, for example, maintained their conceptions of science as a factual body of knowledge representing the objective truth about the natural world throughout their teacher preparation programme and the first year of full-time teaching. In practice, these teachers mainly relied on mandated textbooks and sought single correct answers instead of divergent students' ideas when they ask questions.

In Tanzanian context, the beliefs about knowledge that teachers hold may be inferred from their sociocultural background. African societies believe in unified epistemology in which all knowledge comes from deities and ancestors through elders to children (Hamminga, 2005). Deities reveal all knowledge to elders through ancestors instead of human intellectual discovery. Revealed knowledge is prefabricated, fixed, and readily usable. It can only be interrogated, revised, or discarded through further revelation but not through human intellectual endeavours. Since teachers grew up in the African cultures, they may hold similar beliefs about knowledge and they may bring into teacher education such cultural modes of thoughts as their subjective realities. How such cultural beliefs resonate with the assumptions about knowledge underpinning the reformed secondary science curriculum is the subject that has not been critically examined in the context of Tanzania. This study, therefore, explored science teachers' beliefs about scientific knowledge and how these cohere with the basic assumptions about knowledge that underpins secondary science curriculum in Tanzania.

Methods

This section describes the methodological approaches used to explore teachers' beliefs and analyse science curriculum. For ethical reasons the names of the schools and teachers are expressed as pseudonyms. Further, the ward and district names as well as the exact numbers of students are concealed to protect identities.

Context and participants

The participants were science teachers from one community secondary school and one private secondary school, both belonging to the majority school types in Tanzania. The two schools were conveniently accessible to allow successive interviewing, which proceeded alongside data analysis.

Getamock, a small private school in the central Dar es Salaam had around 400 students split into streams of less than 30 students each. The overall teacher-student ratio is far below the district figure of 1:26 but close to the national teacher-student ratio of 1:20 for private schools (PMO-RALG, 2014). Getamock is far better equipped with school laboratories, electrified classrooms and adequate number chairs and desks.

Marera, a large community school located on the outskirts of Dar es Salaam had over 1500 students divided into streams of over 70 each. The overall teacher-student ratio is slightly above the district figure of 1:33 and far beyond the teacher-student ratio of 1:26 but within the national standard of 1:40 (PMO-RALG, 2014). The classrooms were overcrowded compared to Getamock although each student had a chair and a table. The science laboratories had only essential supplies.

To get in-depth insights from teachers of varying demographics, I invited five science teachers in each school after considering their background information extracted from the staff list. Out of the ten teachers I invited, only six volunteered to participate in the study (see Table 2).

Table 2: *Teachers' Profiles*

	Marera			Getamock		
Teacher	Alex	Nuru	Deman	John	Alfred	Florian
Gender	Male	Female	Female	Male	Male	Male
Experience (years)	5-10	20-25	30-35	1-5	5-10	10-15
Qualification	Diploma (Ed)	BSc. Ed	M.Ed	BSc. Ed	Dip. Electronics	BSc. Ed.
Teaching Subject	Physics	Biology	Chemistry	Biology	Physics	Chemistry

Data collection

To develop a deeper understanding of science teachers' epistemological beliefs, the study adopted an interpretive approach (Lincoln & Guba, 2013). Furthermore, the study used semi-structured interviews to elicit teachers' espoused beliefs about scientific knowledge. It also reviewed the literature on teachers' beliefs about knowledge in other contexts to identify the key dimensions of the beliefs to explore during the interview (Bryan, 2012; Fives & Buehl, 2016; Glackin, 2016; Hutner

& Markman, 2017; Schommer-Aikins, 2004). Afterward, guiding questions on each dimension of beliefs were formulated (see Table 3).

Table 3: *Dimensions of Beliefs and Sample Questions*

Dimension	Sample questions
Legitimate knowledge	If science knowledge in books differs or contradicts from what you know from experience, which one would you trust most? Why?
Knowledge development	Do you think science knowledge changes? Or is it something that does not change? Why do you think so?
Knowledge negotiation	Suppose your student disagrees or questions the accuracy of the procedure or solution to a problem you presented, how would you justify your position?
Justifying knowledge claims	Suppose your student disagrees or questions the accuracy of the procedure or solution to a problem you presented, how would you justify your position?
Knowledge integration across disciplines	How do you view students who use knowledge from other subjects or topics to respond to questions on the subject you are teaching?

Interviews were integrated into the daily routine of teachers. Then, the researcher sat with teachers in their offices which are in the school laboratories. Teachers often marked test scripts and workbooks or prepared lesson notes. These activities served as starting points and contexts for our conversations. For example, an interview with a teacher who was marking scripts would pick on the activity with a question "what pattern of responses did you expect for this or that question and why?" Afterward, we extended conversations by inviting teachers to think aloud about the questions in the interview protocol. The interviews thus moved between informal and formal conversations with the participants controlling the pace and order of questions while the focus was maintained.

Analysing the curriculum documents

The curriculum documents were analysed to establish its epistemological underpinnings. I confined analysis to the general curriculum document for all subjects (MoEVT, 2013) and the syllabi for Physics, Chemistry and Biology for secondary schools in Tanzania. I believe the assumptions about source, structure and stability of science knowledge that underlie science curriculum are reflected in these documents.

Schommer's model was used to identify the assumptions about the source, structure and stability of science knowledge reflected in the curriculum. The curriculum, for example, requires teachers to promote students' 'understanding of how scientific knowledge is created, evaluated, refined and changed within different subject areas' (MoEVT, 2013, p. 15). Based on my interpretation, 'understanding how scientific knowledge is created' reflects assumption about the *source* of knowledge and 'understanding how scientific knowledge is [...] evaluated, refined and changed' reflects assumptions about the *stability* and *certainty* of science knowledge (Schommer, 1990, emphasis added). Statements reflecting the epistemological underpinnings of the curriculum were collected and analysed these along with the interview transcripts as further explained in the subsequent section.

Data analysis

Data analysis sought to discern common ideas, patterns and themes to build a thematic structure which reflects beliefs collectively held among the six science teachers. Narratives of the six science teachers were subjected to thematic analysis procedures (van Manen, 1990). This involved reading the transcripts for familiarisation while underlining the key phrases and words that conveyed the meanings. It was an insightful process of asking myself what statements or phrases in the text seemed revealing about teachers' beliefs? Then, such statements were circled or underlined and notes were written on them to indicate the potential patterns and initial interpretation. This is what van Mannen (1990) called a *selective or highlighting* process of isolating themes.

Afterward, initial codes were generated from the underlined phrases and combined these into themes which I reviewed to ensure that they do not overlap and are clearly distinct. Similarly, I read curriculum documents to identify and highlight the statements that portrayed the epistemological assumptions. Next, I subjected such statements to thematic analysis procedures and generated a list of themes which I organised to form a thematic structure that reflect the epistemological assumptions of the curriculum.

Findings

Findings show that science teachers hold beliefs about subject matter of science, which both resonate and conflict with the epistemological assumptions underpinning secondary science curriculum. Science teachers' beliefs about scientific knowledge were thematically described followed by the assumptions about knowledge underpinning Science Curriculum for secondary education. Next, the (in) congruity between teachers' beliefs and the assumptions about scientific knowledge that underlies the curriculum were discussed.

Science teachers' epistemological beliefs

Science teachers described science knowledge in seven diverse ways along the dimensions of what they considered a legitimate knowledge, its source, nature and structure.

Facticity of scientific knowledge

For the teachers, science is a body of facts derived directly through objective observation of natural phenomena. Facts including scientific laws, principles and theories mirror the 'real' natural phenomena. Teachers believe scientific propositions, which constitute the content of school science are directly observable through senses of perception. Alfred illustrated, 'when we say incident angle is equal to reflection angle…it is real and students can see it.' Likewise, Alex expounded:

> What we teach in science truly exist. For example, Archimedes' principle… when you measure upthrust-the weight of an object when measured in a weighing balance is the same as the amount of water displaced. That is exactly what Archimedes said. You can prove it in the laboratory… for sure it's real.

Teachers believe scientific observations are free from personal dispositions, thus scientists describe the natural world truthfully in absolute sense. Experts' authority and authenticity of observations justify teachers' absolutist beliefs about science. For example, an account of the relationship between the incident angle and reflection angle is real because teachers and students can observe and prove using their senses of perception.

Although scientists partly derive scientific knowledge from empirical observation, this empiricist view of science is largely narrow because a great deal of scientific knowledge is inferential rather than concretely observable. Scientists make inferences and offer explanations about phenomena that they cannot directly observe via senses of perception (Lederman, Abd-El-Khalick, Bell & Schwartz, 2002).

Knowledge authority

Teachers hierarchically arranged knowledge sources with textbooks being the most credible sources followed by knowledge acquired from former teachers. Portraying herself as a knowledge authority Deman said ‘I tell them [students] the truth as it is in the book and they should believe me as their teacher.’ This suggests that teachers see themselves as ‘masters of the subject’ who command a justifiable knowledge authority that students must believe. When asked how he could justify his knowledge claims to a sceptic student, John remarked:

> I don’t think there will be disputes because we have books to guide us. It is a matter of referring to our books. Isn’t it? Because it doesn’t mean that what you are teaching is coming from your brain, you took it from somewhere. So, I don’t think if your mind is the source, there will be a source! You can just show them [students] the source.

Teachers believe knowledge is in the external realm different from learners’ minds. For them, the credibility of the knowledge is justified based on authority. What authority claims to know is truth because the authorities including teachers believe so. The notion of teacher as a knowledge authority is at the core of ‘being a teacher’- a master of subject as Deman remarked ‘as a teacher, I tell students what’s correct, the truth. I can’t teach them lies.’ Consequently, teachers interpret a student interrogating about the knowledge they deliver as challenging the truth of such knowledge and undermining the authority. Alex asserted ‘No! a student can’t argue with me about physics (pause) they can’t, for instance, say “teacher that answer is wrong or that formula is wrong” aah No!’

Knowledge negotiation

Although the production of scientific knowledge inherently involves negotiation based on evidence and justifications, teachers’ account of science suggests that for them knowledge is not subject to negotiation. Teachers, for example, dismissed the possibility of students scrutinising or arguing about the knowledge they teach. Nuru commented ‘Eeeh! No, it can’t happen. Honestly! A student arguing with me? Haa!’ It seems that the hierarchical teacher-student relationship and the beliefs that glorify teachers as subject experts legitimises teachers’ unquestionable authority and control over what counts as a credible knowledge. Consequently, as Nuru asserted ‘students are accustomed to believe that teachers know everything’ and ‘students rarely contest knowledge claims.’ Indeed, teachers see their role as ‘telling students the truth’ they need to know as novices. John gave an elaborate view stressing on the teachers’ superiority:

> What I believe is that between a teacher and a student (pause) a student! That is a novice brain and a teacher is a big brain, now the adult brain should rule out small brain ha ha ha ha! They say, 'a chick cannot teach a hen how to fly.'

The notion of 'big' and 'small' brain suggests that teachers accord students an inferior position of compliant receivers rather than co-constructors of knowledge through critique, dialogue, and negotiation. Indeed, the ideas that students contribute during the lesson are illegitimate knowledge given that teachers accord an inferior position to students. Implicitly, these findings suggest that teachers may perceive the curriculum principle that requires them to promote students' interrogation and reconstruction of established knowledge as a type of teaching that undermines their authority.

Fixity of scientific knowledge

Teachers believe that scientific knowledge is definitive thus, uniformly, and universally presented across books. For them, scientific knowledge is generated through objective observation and subjected to rigorous testing, and verification. Such knowledge is free from errors and prejudices. Florian remarked 'in science when the experiment is done, there is a little room for change… scientific laws and principles that have been investigated and tested for a long time are fixed forever.'

Further, scientific knowledge is definitive because it always mirrors the real world and is practically testable. Florian explained 'Science is hands-on… I mean things are done practically, so science does not change easily.' Likewise, Alfred said 'Newton's laws have been there for centuries… these have been tried and applied all over the world and are stated the same in all textbooks.' The fact that the same scientific knowledge is consistently applied for centuries justifies knowledge absoluteness as John remarked: 'If Biology changes, why would doctors keep learning the same? If you say it changes, why are we teaching the same for decades?

For teachers, science progresses through the continual accumulation of facts which add up to the knowledge repository. Deman exemplified that 'maybe there might be additions or elaborations but to make ammonia we use the same formula; you follow the same procedure, nothing else has ever happened.' Teachers' views of science as fixed knowledge are simplistic for rivalry and disputes are inherent in the process of generating and interpreting scientific evidence (Lederman et al., 2002). This makes multiple or even rival accounts of the same phenomena possible. Besides, scientists' subjectivity and theoretical position influence the creation, interpretation, and description of evidence and eventually the knowledge which forms the school science. In short, the science that teachers see as a purely objective account of natural phenomena is often socially constructed within scientists' frameworks of thinking and their worldviews (Bartos & Lederman, 2014; Lederman et al., 2002). Such socially constructed knowledge is subject to review and reconstruction when a different framework of viewing the world is used.

Clear-cut answers to scientific questions

Teachers view scientific questions as having clear-cut right or wrong absolute answers. This makes it possible to determine precisely right or wrong answers beforehand. John emphasized that 'Science […] is a real answer. I mean it is one and the only answer, so it's the same for everybody. If you get it right, you get it right, if it's wrong, it's wrong.' These remarks suggest that teachers believe scientists unambiguously and interpret evidence to produce clear-cut answers to the scientific questions they pursue. Conversely, scientists often do not directly discern answers from evidence, instead, they negotiate or conventionally decide upon the interpretation of the evidence and, eventually, upon valid answers to the problems they investigate (Abd-El-Khalick, 2013). Therefore, scientific questions often have no clear-cut answers as teachers tend to advocate.

Knowledge disintegration

Teachers' account of cross-disciplinary connectedness of scientific concepts indicates deeper boundary disputes about what belongs to which subject. For them, school subjects and concepts within subjects constitute discrete unrelated facts. John elaborated: 'you can't tell me that there is a relationship between my Biology and Physics calculations on pressure or force? I think there is not.' Likewise, Alfred said: 'I don't think there is a Chemistry or Biology topic that is directly related to Physics topics. Even Physics topics themselves are not related, for instance, you are teaching electricity, how is density relevant there?'

Remarks such as 'How is density relevant there?' suggests that, for teachers, knowledge exclusively belongs to discrete subjects. The subject content stands in isolation from the rest with clearly demarcated boundaries. In keeping with their beliefs, teachers see themselves as monopolists of their subject knowledge as Deman remarked: 'what I teach in Chemistry is for Chemistry.' Such narratives reflect teachers' beliefs about the structure of scientific knowledge. To justify their beliefs in the disciplinary specificity of knowledge, teachers referred to how knowledge is organised in textbooks and core curricula documents. Nuru remarked: ‘Even books treat different chapters distinctly…because these are not related.’ These views suggest that teachers rarely reflect and make conscious attempts to integrate knowledge by linking school subjects to foster holistic understanding when teaching. By referring to curricula documents such as textbooks and syllabi, teachers are illustrating how the strong framing of knowledge into discrete subjects is inherently part of the school curriculum itself.

Depersonalised knowing

Teachers described science as inert knowledge independent of the personal disposition of the knower. They described knowing science as accruing inert content separate from the personal experiences of the learner. Alex explained: ‘When I say I am learning science it means science is a body of principles, which is there, so I am learning a body of principles.’ They emphasised delivery of uniform knowledge regardless of learners’ prior dispositions, which influence the interpretation and connection between ideas they make. John illustrated: ‘you can’t say now I have understood Boyle’s law, now let me find a way to state it in my own words. It doesn’t make sense! Ha ha ha!’

For teachers, knowing science is about memorising and reproducing expert knowledge as presented in science textbooks. Alex asserted: ‘I think we learn science concepts the way these are presented in textbooks and we follow the principles of learning science. For example, if we say Archimedes’ principle, you state it clearly as it is in a book.’ ‘stating it clearly … the way this [content] is presented’ suggests that knowing involves reproducing textbook knowledge without negotiating the meaning or making personal connections between concepts and wider contexts. Teachers emphasised ‘precision’ in terms of similarity with the textbook content. John exemplified: ‘in science, we should be precise … because these are laws that scientists created. What students need is to absorb them [the laws] from a book rather than putting [articulating] the way they think or want.’

Overall, teachers espoused views that detach first-hand experiences from the process of knowing. They prefer students to articulate scientific ideas using conventional vocabulary, thereby portraying knowing as an objective value-free process. At a deeper level, teachers’ views reflect their conceptions of valid knowledge which exclude students’ everyday ideas and experiences. Under this circumstance, students may feel restricted to contribute their thoughts and experiences especially when such ideas are inconsistent with the mainstream science presented in textbooks. In what follows, I describe the key assumptions about scientific knowledge that underlies the curriculum.

Epistemological assumptions underpinning secondary science curriculum

The analysis found five key assumptions about knowledge underlying the current secondary science curriculum in Tanzania. I thematically organised these as presented in the subsequent section.

Knowledge acquisition

Promoting knowledge acquisition is the most basic philosophy of the curriculum reflected in the aims of secondary education. The curriculum requires science teachers to help students 'develop mastery of fundamental concepts, principles and skills of [science] and the related fields' (MoEC, 2005, p. v). It needs teachers to 'promote the acquisition and appropriate use of… scientific (scientific what?) … and other forms of knowledge' (MoEVT, 2013, p. 11). Knowledge, in this case, is assumed to pre-exist learners and is in the external realm as reflected in the phrase '[the] curriculum [will] allow the gathering of knowledge from… diverse subjects' (MoEVT, 2013, p. 17). Implicitly, 'the gathering' of knowledge illustrates the ascription of ignorance to a learner who must 'gather' knowledge from external sources (Bruner, 1996).

Consistent with a view of learning as 'gather[ing]', the curriculum presents subject knowledge as information that a learner 'gathers' and piles up to build a knowledge repository. Such assumption manifested in the way subject knowledge is organised into separate disciplines with emphasis on the symbolic boundaries between subjects (Bernstein, 2000). Symbolic boundaries are evident in the way the lesson activities and tasks are strongly framed based on the time and pace of transmission. The curriculum, for example, states that 'a week of teaching shall have a minimum of 40 periods and each period has a duration of 40 minutes. The daily total instructional time shall be 5:20 hours' (MoEVT, 2013, p. 17). Such statements signify knowledge fragmentation.

Modeling science process skills

The curriculum demands teachers to help students to model scientific inquiry. It requires teachers to promote imaginative, intuitive, creative, interrogative, and evaluative thinking. Statements advocating inquiry learning include 'teachers should help students develop intuitive and imaginative thinking [and] ability to evaluate [scientific] ideas, processes, and experiences in meaningful contexts' (MoEVT, 2013, p. 14). To achieve this goal the curriculum requires teachers to 'plan and design relevant tasks that will let students question, critically think, form new ideas, [and] create artifacts' (p. 29). These statements contain a number of assumptions about the nature of knowledge.

First, asking teachers to encourage students to 'evaluate scientific ideas, processes and experiences' illustrate an assumption that scientific knowledge is subject to interrogation and review. This is a shift away from a view of science as absolute knowledge propagated through mandated curriculum (Abd-El-Khalick, 2013; Lederman et al., 2002). Furthermore, encouraging teachers to promote intuitive, inventive, and imaginative thinking about science suggests that the curriculum favours a view of scientific knowledge as invented rather than discovered account of natural phenomena. It suggests that creating scientific knowledge essentially involves human inferences, imagination, and creativity (Lederman et al., 2002). Overall, the curriculum emphasises scientific inquiry and the experiential nature of knowledge construction.

Constructing multi-perspective worldviews

The curriculum draws on the constructivist theory of learning by stating that 'learning shall be rooted in the conception of constructivism' (MoEVT, 2013, p. 29). It requires teachers to 'encourage students to access wider sources of knowledge including information related to science and other fields for self-study and life-long learning' (MoEVT, 2013).

By adopting constructivism, the curriculum envisions a learning environment in which students construct scientific knowledge based on their prior experiences (Taber, 2014). Since the students embody their unique prior experiences, the personal knowledge they construct about the natural phenomena is presumably unique reconstructions of various sources they encounter. In other words, the curriculum is inspired by the principle that emphasises the construction of multi-perspective worldviews by encouraging teachers to help students interpret established bodies of knowledge.

In keeping with constructivists' principles, the curriculum advocates meaningful learning. It states that teachers should design tasks that bring sense in the learning process and the learning that makes sense in the life of students (MoEVT, 2017)

Implicitly, the curriculum advocates experiential learning in which learners connect the established bodies of scientific knowledge and their own experiences and reasoning. By subscribing to constructivists' principles, the curriculum advocates a change from a view of school science as inert ideas that students passively absorb to something they should 'think [about] reflectively and logically' (MoEVT, 2013, p. 14).

The curriculum advocates a view of knowing as a personal processing of knowledge for it requires teachers to encourage students to 'think for themselves.' Further, it embraces collaborative learning by teachers to help students 'recognise the limits of individual reflections and the need to contribute to and build upon mutual understanding' (MoEVT, 2013, p. 14). Building upon mutual understanding indicates that knowledge is negotiable based on evidence and reasoning. It illustrates a shift away from a conception of knowledge as being a definitive account of the natural world (Lederman et al., 2002).

Discussion and Conclusions

This study explored science teachers' beliefs about scientific knowledge and how these beliefs compare with the basic assumptions about knowledge that underpins Science Curriculum for secondary education in Tanzania. Overall, science teachers' beliefs about what constitute legitimate science knowledge and how it should be taught largely conflict with the epistemological underpinnings of the curriculum, thus, duelling paradigms.

Generally, while the teachers appear to cling to their naive conceptions of science as objective, fixed, and absolute account of the natural world that exists *a prior* and is detached from the subjectivities of the knower (Hofer & Pintrich, 1997), the curriculum is largely founded on the constructivist epistemology. Some of the assumptions underlying the curriculum, however, resonate with the teachers' held beliefs, thus making the curriculum self-contradictory for favouring diametrically opposed epistemological assumptions. In what follows, I compare science teachers' beliefs with the epistemological foundations of the curriculum to establish the congruity. Further, I used empirical and theoretical literature to illuminate on the implications of conflicting knowledge paradigms for pedagogic practice.

To start with, the idea of 'gathering of knowledge' that manifests in the curriculum coincides well with teachers' conceptions of knowing science as the acquisition of inert knowledge from the external authority. It resonates with teachers' description of knowing as memorising discrete pieces of subject content that adds up to form knowledge repository. Both teachers and the curriculum seem to favour a view that detaches knowledge from everyday experiences and subjectivities of the knowers. In education systems where objectivist epistemology underpins the curriculum, knowledge is considered definitive and students are encouraged to search for such knowledge in the external realm (Tabulawa, 2013).

Further, the way teachers described school subjects as if they constitute isolated pieces of knowledge closely coheres with the way curriculum emphasises the boundaries demarcating school subjects. Indeed, science teachers' tendency of referring to curriculum to justify their beliefs in the disciplinary specificity of knowledge illustrates their experience with strong framing and symbolic boundaries between knowledge domains, that are embedded in the curriculum documents. Where the education system is underpinned by objectivism, knowledge is seen as isolated bits and pieces of information that learners unambiguously accumulate and store (Schommer-Aikins, 2004). Indeed, compartmentalisation of school subjects and concepts in the curriculum illustrates the objectivist epistemological assumptions (Abd-El-Khalick, 2013). Beyond the two assumptions discussed above, science teachers held beliefs about the structure, source, and stability of knowledge that are incompatible with the epistemological underpinnings of the curriculum.

Whereas constructivist epistemological assumptions underlie the curriculum, teachers espoused strong absolutist beliefs about science. The curriculum assumes socially negotiated knowledge in a classroom environment that values and encourages multi-perspective account of the natural world including from students' everyday experiences. It advocates teaching and learning environment that are open to dialogue and considerations of alternative sometimes competing knowledge claims and solutions drawn from students' experiences. In contrast, teachers view science as a pursuit of a single definitive truth - an account of the natural world that experts discovered, fabricated, and codified in science textbooks. For them, science is certain and absolute thus they consider legitimate alternative claims unreal (Tabulawa, 2013). Consequently, instead of encouraging dialogue, teachers advocate transmitting textbook knowledge. For them, every scientific question or problem corresponds to one definitive answer derived from authoritative knowledge sources.

Further, while the principles that require teachers to encourage students to interrogate, evaluate and critique authoritative knowledge sources underpin the curriculum, teachers believe scientific knowledge is definitive, thus, not subject to interrogation and critique. Seeing scientific knowledge as less subject to critique illustrates a lack of an understanding of the fact that contentions are inherently part of how scientific knowledge came into being. Rivalry in which scientific evidence and claims are interrogated, critiqued and changed to negotiate legitimacy is part of scientific practice. Such principles, which characterise scientific enterprise are reflected in the curriculum goals, which envision teaching and learning that encourage students to critically think, evaluate and questions scientific ideas to arrive at their own conclusions (MoEVT, 2013).

Lastly, teachers espousing views of learning that detach students' imaginations, interpretations and creativity from knowing contradict curriculum principles that advocate learning as knowledge construction based on learners' everyday experiences. Indeed, knowledge construction is unthinkable in classroom context where teachers see science as a lifeless content separate from the person of knower. In such contexts, teachers are likely to encourage learning that involves accruing inert content without making personal interpretations and connections with a prior experience. Such classroom discourses are incompatible with the curriculum that is informed by the assumption that the creation of scientific knowledge inevitably involves negotiating soundest interpretation of evidence within the frameworks of experts' presuppositions and theoretical commitments (Lederman et al., 2002).

Overall, science teachers held beliefs about scientific knowledge that largely contrast the assumptions about knowledge that underlie Science Curriculum for secondary education in Tanzania. The findings of this study may be limited in two important ways. First the sample of six science teachers is rather small such that it limits the generalisability of the findings. Further, the study relied on science teachers' self-espoused beliefs which may not necessarily manifest in their classroom practices. However, when interpreted carefully, the results bear important implications for teachers' classroom practices as discussed hereunder.

Implications for Curriculum Implementation and Classroom Practice

It is widely recognised that when science teachers' beliefs are inconsistent with the principles that underlie the curriculum, teachers either reject the curriculum or implement it superficially consistent with their deeply held beliefs (Bryan, 2012; Fives & Buehl, 2016). Conversely, when the basic philosophy of the curriculum resonates with their beliefs, teachers are likely to enthusiastically implement the curriculum (Fives & Buehl, 2016). Since teachers in this study espoused beliefs about science that largely contrast the basic epistemological underpinnings of the curriculum, it is likely that such inconsistencies will be implicated in their actual classroom practices.

Teachers inspired by naïve views of scientific questions as having simple one-to-one correspondence are likely to prefer asking closed factual questions and seeking single predetermined correct answers consistent with their beliefs (Glackin, 2016). Moreover, their absolutist views of science are likely to bear on what they will consider a legitimate knowledge and correct answers to questions. Given that they accord high status to authoritative sources, their standard for judging the validity of answers and ideas is likely to resemble with the established knowledge sources rather than evidence and justifications as envisioned in the curriculum (Mansour, 2013). Such teachers are likely to limit the space for probing, debating, and considering multiple perspectives. For them, it will be needless to encourage students to generate or construct multiple accounts different from textbook knowledge which they consider to be certain.

During the actual teaching, teachers holding absolutist views of science are less likely to favour pedagogical modes that allow space for students to actively analyse, critique and improve knowledge as envisioned in the curriculum. If knowledge is seen as absolute, it cannot be subjected to critique and change. Thus, for such teachers, allowing space for students to contribute evidence and experiences that critique and expand knowledge boundaries beyond established frameworks would be needless (Park et al., 2010). Indeed, teachers are likely to see the curriculum principle requiring them to transfer control of knowledge and treat students as 'equals' as undermining the authority and power traditionally accorded to them (Hamminga, 2005). Such teachers might feel undermined when they must encourage students to interrogate the knowledge they teach. Therefore, they are likely to reject or modify the curriculum principles on the grounds of being inconsistent with their deeply held beliefs and avoid undermining their position of knowledge authority.

In this paper, it has been shown that, science teachers' beliefs about scientific knowledge conflict with the epistemological underpinnings of the curriculum. It has been discussed how such diametrically opposed epistemologies could influence science teachers' pedagogical practices. I concur with Bruner (1996) who observed that any pedagogical innovation inevitably competes with the folk beliefs that teachers and learners bring into the classroom. To this end, it can be added that science teachers in Tanzania could be resisting learner-centred pedagogy partly because the epistemological underpinnings of the curriculum are averse to their well-established beliefs.

Considering the nature of science teachers' epistemological beliefs and how these resonate with the curriculum, it is imperative that teacher educators in Tanzania endeavour to change such beliefs. To adopt learner-centred pedagogy, teachers need to ideologically align with its basic principles reflected in the curriculum. Therefore, teacher educators and policymakers should not only focus on equipping teachers with knowledge and skills on how to teach using learner-centred pedagogy but also interrogate and transform pre-existing teacher beliefs that are likely to militate against the principles underlying reforms.

In Tanzania, teacher education and professional development ought to be equipped with learning trajectories that provide opportunities for teachers to identify, reflect on, challenge and transform their beliefs (Hofer & Pintrich, 1997). Such trajectories should offer alternative beliefs drawn from the assumptions about knowledge that underpins the curriculum. To help student teachers develop sophisticated understanding of science, teacher educators should provide opportunities to reflect on how scientists create, review and change scientific knowledge.

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