The *i*SPACES Framework to Restructure Culturally Responsive Secondary Science Curriculum in Tanzania[1]

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Abstract

The ***i*SPACES** project for teaching a culturally responsive science curriculum in Tanzania emphasizes practical skills to develop scientific knowledge among secondary school students. *i*SPACES employs a framework that involves interdisciplinary teaching to motivate students to study science, technology, engineering and mathematics (STEM) and to produce useful products that will fill needs encountered in real life. This discussion considers methods for restructuring an existing curriculum and rethinking the methodologies for teaching of physics, chemistry and biology (PCB) to overcome students' cognitive conflicts between their everyday world and the world of academic science. The examination concludes with an illustration of curriculum structure that may guide teachers who wish to rethink PCB pedagogy and designers who want to create culturally responsive curricula.

Introduction

Cognitive conflicts between everyday life and the world of academic science continue to thwart students' learning of science and intimidate women and minority students from enrolling in STEM subjects (Semali & Mehta, 2012). An interconnected web of challenges face the current science education in East African schools; for example, formidable obstacles exist that prevent teachers from bridging the gap between students' lived experiences and STEM science taught in classrooms—obstacles such as scarcity of textbooks or poorly equipped science laboratories, lack of quality training for science teachers, and the devaluing of students prior knowledge of informal science (Semali et al., in press).

These problems, coupled with poor remuneration for teachers, lead to inefficient teaching and learning. Conditions interrupt or cripple the development of scientific skills of women and minority students from poor and indigenous communities or students with rural backgrounds at an early stage of academic life. Sometimes minority students are simply discouraged or excluded from science education because they do not have interest or are perceived not to be sufficiently "intelligent" to cope with science, technology, engineering, and mathematics (STEM) (Semali & Mehta, 2012, p. 2).

This discussion describes restructuring the existing science curriculum in Tanzania and rethinking the pedagogy of physics, chemistry and biology (PCB) to overcome students' cognitive conflicts between everyday life and academic science. The examination also considers avenues for transforming mainstream (western) secondary science curricula to accommodate

[1] This is third article in a series that describes the *i*SPACES experiment (see Semali & Mehta, 2002; Semali, et al. in press.). Many individuals who contributed to this project in Tanzania and in the United States; the developers of the curriculum's materials, and colleagues who read several drafts and whose comments were most valuable to improve the manuscript require grateful acknowledgement.

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minority students, remote area students, and women from impoverished communities to fill the gap that culturally non-responsive curricula cannot accomplish.

Culturally responsive pedagogy facilitates and supports the achievement of all students. In a culturally responsive classroom, effective teaching and learning occur in a culturally supported, learner-centered context, which identifies, nurtures, and uses the strengths students bring to school to promote achievement. Gay (2000) defines culturally responsive teaching as using the cultural knowledge, prior experiences, and performance styles of diverse students to make learning more appropriate and effective by teaching to and through the strengths of these students. For many students, the kinds of behavior required in school (e.g., sitting in one's seat and only speaking when called on) and types of discourse (e.g., "Class, what is a litmus test?)" contrast with domestic cultural and linguistic practices. To increase student success, an imperative is that teachers will help students bridge this discontinuity between home and the two most relevant attributes of teachers' responsibilities: personal and instructional dimensions (Heraldo, et al., 2004).

The Tanzania society has a lot to gain by restructuring its science educational institutions, curricula, pedagogy, and praxis such that all learners, regardless of age, ethnicity, religion, gender, or disability, can excel in science education and become innovative and productive citizens. Besides, there exists urgent need in the era of global economic expansion and the era of growing awareness among science educators to relate science more closely to the learners' societal or cultural environments, thereby minimizing the conflicts that might arise from local views of the world and that of science taught in schools (Clark, 1997; Semali, 1999). Given that innovation is a major driving force in economic growth and social development, the issue becomes finding methods for teachers to encourage integration of practical innovative skills and habits in science classrooms. Instilling the 'can do' attitude in youngsters studying STEM subjects is the core concern.

Characteristically, the current educational system in Tanzania, especially in government-operated secondary schools, presents a wide range of subjects in the "ordinary level" (up to 19-21content area subjects in some schools). This practice leads to a more theoretical coverage of material, requiring students to rely mostly on "rote" learning instead of "practical" explorations. Science education is important for any developing country in search of solutions for endemic problems and for solving problems related to poverty, hunger, and disease. A culturally responsive secondary science education that is accessible for all students can transform current curricula and pedagogical practices to an approach no longer exclusive for male students who come from privileged families.

The focus of the *i*SPACES project, as described in this discussion is leveraging STEM science principles to create workable solutions for overcoming problems associated with poverty, famine, disease, climate change, and the depletion of non-renewable natural resources. Conceptually, ***i*SPACES** represents an acronym that stands for ***i***nnovation, **S**cience, **P**racticals, **A**pplication, **C**onceptualization, **E**ntrepreneurship, and **S**ystems. This interdisciplinary project emerged from a quest by stakeholders who analyzed and criticized the degree of practicality of science taught in schools by querying method for schools to engage students in generating participation in developing solutions for overcoming poverty. The answer entails determining if a community's informal or indigenous science regarding food security can increase agricultural yields, preserve grains, fruits, and vegetables, and prevent/treating common diseases affecting humans and livestock as constituents of everyday school science and academic curricula.

Research began with the simple idea that every indigenous culture has an orientation toward learning that is metaphorically represented in its art forms, its ways of life, consistent with the community and its geographical location, its language, and its ways of understanding itself in relation to its natural environment. To operationalize this thinking in the *i*SPACES framework, a preliminary study exposed the core components of inquiry and found theoretically-driven models and practices that are integral to the success of day-to-day science teaching in Tanzania (Results of this preliminary study appear in Semali & Mehta, 2012).

The research sought opinions of parents, classroom teachers, and other stakeholders regarding science education and its presentation in secondary schools. Another aspect investigated is the challenges and barriers that prevent teachers from engaging students in a culturally responsive science curriculum and the reasons for teachers' not designing culturally appropriate instructional methods that align with local needs or problems, such as reducing poverty. Several questions guided the discussions throughout the inquiry process:

1. When employing culturally responsive pedagogies in STEM science, what were the possibilities, barriers, or dilemmas that arose for students and teachers?
2. What strategies and resources were available locally to enable students to demonstrate the breadth of knowledge and understand science as a tool to solve everyday problems?
3. What will be the characteristics of science education when teachers adopt *i*SPACES as a culturally responsive learning environment in which Tanzanian students can engage science (i.e., do science rather than just study science)?

Current problems of a changing society in the midst of a global economic crisis and the fact that indigenous knowledge, worldwide, regarding human health, survival, and innovation is on the brink of disappearing (Semali et al., in press), provide the motivation underlying the innovative *iSPACES* experiment, and the quest for a viable framework for teaching science in East Africa, Tanzania in particular.

Indigenous knowledge is local expertise harnessed and assembled by communities over generations, reflecting many years of experimentation, innovation, and discovery in all aspects of life. Indigenous knowledge is uniquely valuable to every community, from providing insights and information that directly reflect the opinions, values, and attitudes of the local people engaged in initiatives of community development. Throughout history, indigenous knowledge was orally-transmitted or transmitted through imitation and demonstration and is the consequence of practical engagement in everyday life which reinforces with experience, trial and error, and conscious experimentation.

Tanzania's secondary science education is an artifact of the British colonial education system. The curriculum, books, and teachers were, until recently, overseas imports (Semali & Mehta, 2012). For example, textbooks, published by Macmillan or Heinemann in England and distributed through subsidiaries established during the colonial period in neighboring colonial countries, were in English and used examples and metaphors divorced from indigenous knowledge or written with the expectation that teachers would supply applications appropriate for the locale.

The subjects: physics, chemistry, and biology, written with a focus on memorization, had the intention of preparation for the London and Cambridge University entrance examinations, and more recently, examinations from the Tanzania National Examination Board. For these reasons, as apparent in current textbooks and the language of instruction (LoI), the designs of concepts, curricula, and pedagogy did not include culturally responsive aspects.

The legacy of colonial education has lingered through the present. Most textbooks remain imports; local teachers have no adequate preparation for teaching STEM subjects; teachers and students are not proficient in LoI (English), and women continue to encounter discouragement from attending science courses (Semali & Mehta, 2012). The content of subjects taught in classrooms neither reflects local needs, local conditions, nor accounts for indigenous ways of knowing and thinking when solving local problems.

The study proposes the *i*SPACES framework of teaching a culturally responsive science curriculum. First, a discussion of theoretical considerations outlines a culturally responsive curriculum. Second is an explanation of *i*SPACES' pedagogical framework, and the third consideration is description of the *i*SPACES framework for teaching science that calls for a curriculum structure purposely designed to develop practical solutions. The final discussion includes conclusions and prospects for future research.

***i*SPACES as a Pedagogical Strategy**

The *i*SPACES project is an experiment that offers an interdisciplinary approach to teaching science as practical to generate a "to-do" attitude among students. As a pedagogical strategy, the concept of *i*SPACES entails a variety of theoretical, disciplinary, and epistemological perspectives represented in the acronym, namely, Engineering, Education, and the Sciences. The strategy proposed in the *i*SPACES's framework aims to transform mainstream curriculum one among many approaches, by synthesizing appropriate research into pedagogical principles and science content that is readily usable by teachers. Within this approach, teachers focus on problem-solving to enable graduates of secondary school science to learn and master science concepts, leverage indigenous knowledge, and share, authenticate, enhance, and analyze the knowledge of everyday life. This framework encourages students to think, plan, and act in ways that can help to solve problems or alleviate adverse local conditions.

To promote such a "*to do"* attitude in science classrooms is important and significant for a nation that championed "*Education for Self-Reliance*" in the early 1970s, and one that the legacies of colonialism, poverty, disease, and ignorance continue to plague (Nyerere, 1968). The *i*SPACES framework emphasizes culturally responsive pathways for learning science that: (1) involve teaching practical skills to develop scientific expertise, (2) employ a pedagogy that hinges upon participatory instruction, learning techniques, and innovation, and (3) in an entrepreneurial atmosphere, rewards critical exploration that focuses on solutions to local problems.

The traditional science curricula currently promoted by the Tanzania Institute of Education, as observed by Semali and Mehta (2012), involves strict regulation of curricular materials and establishes a discipline that disregards the capacities and interests of students' indigenous knowledge, including ignoring conditions and the environment in which students live. This observation is of particular significance to African students who struggle to link what transpires at school in science classrooms and its relationship with what occurs at home.

As a result of years of devaluing indigenous knowledge and neglect of local examples, science teachers have not managed to address students' cognitive dissonance resulting from the conflict between home science and school science (Semali et al., in press). For example, locally produced textbooks that link what people know and do in their immediate surroundings with current school scientific frameworks for environmental conservation or natural disaster management are difficult to obtain. This discussion probes methods for employing the "learning science community" to reduce the persistent conflicts between the world of everyday life and the world of school science. Also explored are the capabilities, or lack thereof, that allow teachers to transform the academic environment into a culture that values science as part of students' lives, and consequently, the opportunities for sustainable careers in science.

Developing Culturally Responsive Teaching and Learning

To discover guidelines for culturally responsive science instruction and learning, the *i*SPACES project aims to address the current separation of school and home. For example, Tanzanian secondary school teachers and students continue to interact with indigenous and curricular-based natural science but rarely do teachers attempt to describe, use or ultimately assign value to culturally-oriented, local science. Little research has attended to integration of knowledge bases that addresses the cognitive dissonance between knowledge transmitted through instruction in science classrooms and knowledge acquired through interactions in local, out-of-school contexts. This study proposes that *i*SPACES can transform the situation (Semali & Mehta, 2012).

Although the field of education has progressed towards understanding the complex issues facing schools that serve minority or underserved students, fundamental changes at the classroom level have yet to materialize. That level, the classroom, represents the stage for researchers, teachers, experts, and students, communally, to contribute to solving the pressing problems (Villegas, et al., 2002). Today's classrooms require talented teachers to educate students who vary in culture, language, abilities, and other characteristics (Gay, 2002). One proposed change is to teach science using a framework of culturally responsive pedagogy (Laughter & Adams, 2012; Ladson-Billings, 1995). The Ladson-Billings' proposal suggests three guiding principles for curricular design: (a) development of a socio-political and critical consciousness, (b) willingness to support cultural competence, and (c) develop students academically (Ladson-Billings, 1995, p. 470). Other characteristics outlined by Gay (2002) include culturally responsive teaching that:

1. Acknowledges the legitimacy of the cultural heritages of different ethnic groups, both as legacies that affect students' dispositions, attitudes, and approaches to learning and as worthy content to be taught in the formal curriculum.
2. Builds bridges of meaningfulness between home and school experiences as well as between academic abstractions and lived sociocultural realities.
3. Uses a wide variety of instructional strategies that are connected to different learning styles.
4. Teaches students to know and praise their own and each other's cultural heritages.
5. Incorporates multicultural information, resources, and materials in all the subjects and skills routinely taught in schools (p. 110).

To meet these challenges, teachers must employ not only theoretically sound but also culturally responsive pedagogy. Teachers must create a classroom culture in which all students regardless of their cultural and linguistic backgrounds are welcomed and supported, and provided with the best opportunities to learn.

Ladson-Billings' (1995) three principles and Gay's (2005) five characteristics emphasize the need to acknowledge the socio-cultural origins of students and the knowledge systems that surround them. Using these characteristics to improve culturally responsive teaching would involve significant changes and considerations for reorganizing the classroom environment. Literature in classrooms would reflect multiple ethnic perspectives and literary genres. Math instruction would incorporate everyday-life concepts, such as economics, employment, various ethnic groups' consumptive habits (e.g., farmers, cattle herders, retailers, etc.). Science instruction would engage students' development, expressing and sharing cumulative understanding of science while caring and respecting relationships among people in classrooms and among students' cultural (or informal science) and subject content knowledge (Glynn, et al., 2010).

In practice, therefore, a culturally responsive pedagogy positions students and their communities as having "funds of knowledge" and expertise directly related to their lived experiences (Moll, et al., 2005). Advocates of funds of knowledge stress that a culturally responsive pedagogical orientation focuses attention on cultural competence and reciprocity in the exchange between teacher and learner in which teachers endeavor to create culturally responsive pathways for science learning by incorporating children's and communities' funds of knowledge in the curriculum (Moll, 1992). Likewise, culturally responsive science classrooms support diverse ways of knowing that students bring to school. For these reasons, a culturally responsive science curriculum cannot be taught as a discrete subject but instead must aim to develop in students (a) critical consciousness, (b) supportive cultural competence, and (c) academic development.

Background and Context of *i*SPACES

In 2007, one private university in Tanzania approached researchers at the Pennsylvania State University (PSU) seeking collaboration for development of the *i*SPACES project. As a newly established university in Tanzania, the administrators recognized a need to establish a different kind of program that targets science teachers in addition to the existing departments of theology, arts, and languages. The university administrators observed that some of the newly admitted students to the university were science teachers previously trained to teach physics, chemistry, and biology (PCB) but instead were leaving their teaching posts to join the university to obtain a bachelor's degree in arts and languages. These science teachers were not seeking to continue to study the sciences—the subjects they previously taught in secondary schools, but surprisingly, they were switching to study language arts subjects. This revelation prompted the administrators to rethink their priorities and quickly recognized an opportunity to establish a Bachelor of Science in Education (B. Sc.-ED) at the newly established university.

In the meantime, the PSU team was asked by the Tanzanian university administrators to produce a White Paper that describes the nature of the new science curriculum. The White Paper outlined the rationale for conceptualizing a curricular effort intended to *restructure*, *retrofit* and *complement* rather than replace the current PCB national curriculum, underwritten under the supervision of the Tanzania Institute of Education. One of the objectives was to address the common misconception that practicals[2] are too expensive because they require lab space, and costly chemicals. Equally, practicals require many hours of teachers' uncompensated preparation.

[2] The term "Practicals" refers to the activities students engage in for science laboratory experiments. The *i*SPACES framework uses an experiential approach; most traditional science curricula from the Tanzanian Ministry's Institute of Education use a mixed framework with limited lab experience and often without practicals.

To understand this misconception and to address the myths about science education as a "*hard*" and "*costly*" subject, the research team conducted a survey to capture and verify the state of current science education in Tanzania. Also, through interviews, the team gathered opinions from the teachers who had abandoned teaching STEM subjects and instead preferred to teach the arts. (For detailed results of the survey, see Semali & Mehta, 2012).

The participants of the survey were teachers who taught in different parts of the country and represented various science subjects: physics, chemistry, and biology. Researchers also collected and analyzed data regarding the tensions apparent in participatory action research (PAR), used in the investigation of diverse stakeholders who participated in the project (e.g., teachers, students, parents, curriculum experts, and administrators). In the PSU study, a stakeholder was a person, group, or organization that had a vested interest in the outcome of a decision (Stoecker, 2013, p. 107). In sum, the stakeholders represented a wider social and cultural matrix of society, and their motivations for participation was interest to produce a framework for holistic science curriculum that reflects local Tanzanian educational environment.

The ultimate goal of the study was to determine the feasibility of establishing a different framework that prepared science teachers for the Bachelor of Science degree based on culturally responsive pedagogy that would ultimately value indigenous knowledge and students' funds of knowledge. After broad consultation with diverse stakeholders, the research team held a summit workshop with stakeholders to present results from the survey and data derived from interview protocols. After long deliberations and often heated debates, the *i*SPACES framework that materialized incorporated strategies that involved interdisciplinary teaching, problem-solving, indigenous-informal knowledge, experiential learning, innovation, and critical exploration. Critical exploration in science implies engaging teachers and students as researchers to lead open discussions about what is known; how it is known, as well as understanding motives for and interest in specific types of knowledge and knowledge creation.

Ways of Learning and Doing Science with *i*SPACES

To implement a framework that adopts the *i*SPACES orientation to learning and one that is attentive to culturally responsive pedagogy that is sensitive to students' funds of knowledge, the planners had to establish, throughout the course development process, a collaborative effort that involved local experts, cultural workers, community elders, and practitioners as much as possible. Central to this process was a mechanism that allows free exchange of information and perspectives in which the classroom teacher comes to understand what knowledge is held locally, valued, and by whom. Further, the process involved the connection of these cultural experts and their knowledge to practice in classrooms. The adjusted thinking resulting from critical exploration and free exchange of information postulated that teaching strategies must undergo experimentation, evaluation, challenge, redesign, and perhaps even abandonment.

The pilot study showed that teachers were likely to face multiple challenges from various quarters, stemming from the design of the curriculum, teachers' background knowledge in academic science, pedagogical knowledge, and cultural foundations. In addition, the design of the curriculum, inadequate teachers' knowledge of science, and negative attitudes towards some indigenous knowledge concepts due to neocolonial legacies of devaluing everything "local" negatively affected the outcomes from teaching.

Also, the study showed that teaching science (or any other subject) requires teachers' deep familiarity with the subject and the various paths (styles) learners adopt to comprehend the subject. The discourses or everyday funds of knowledge (Moll, 1992; e.g., prior knowledge, cultural practices, indigenous remedies or solutions), that students bring to school have value as important influences for students' processing science concepts in and out of school (Gay, 2000). As used here, discourses (Gee, 1996) are commonly shared ways of "knowing, thinking, believing, acting, and communicating" (Moje & Lewis, 2007, p. 3) that are present in and out of school and influence teachers' methods and students learning (Moll, 1992).

Shared ways of knowing and familiarity with subject matter helps teachers to use their expertise and authority on behalf of students—to make choices that respect each student's sense-making capacities and nurture each student's interests and development as an individual—rather than striving to maintain fidelity to a programmed national curriculum from the Ministry of Education. For this reason, as expanded upon in the next section, experiential learning and the teaching-research pedagogy of critical exploration represent foundational pillars of the *i*SPACES framework (Cavicchi, et al., 2009; Duckworth, 2005).

The ways of learning and doing science with the *i*SPACES framework rely on practicals that are foundational for experiential learning in and out of classrooms. *Experiential learning* theory refers to learning as "the process whereby knowledge is created through the transformation of experience." The assumption is that knowledge will result from the combination of grasping and "transforming experience" (Kolb 1984, p. 41). Theoretically, Dewey (1916), Lewin (1936), and Piaget (1957) form the *experiential foundation* for the iSPACES project.

Dewey's philosophical pragmatism of experiential education, Lewin's social psychology—based on the vision of "life space" and operate from "group dynamics," and Piaget's cognitive-developmental genetic epistemology for understanding and communicating with children, particularly in formal education (e.g., Discovery Learning), collectively form a unique perspective on learning and development (Kolb, 1984). For example, Dewey in his thesis on education and experience emphasized experience, experiment, purposeful learning, freedom and other well-known concepts of "*progressive education*." Dewey believed that sound educational experience involves above all, *continuity* and *interaction* between the learner and the retained knowledge. The *i*SPACES framework emphasizes the same continuity and interaction between everyday life and the world of school science, namely, school and home.

In sum, the ultimate goal of the *i*SPACES project is to focus on education of teachers offered at Tanzanian teachers' colleges or private universities' baccalaureate degrees. The assumption is that as *i*SPACES becomes widespread and familiar to science teachers, the proposed framework will need experimentation and fine-tuning. Also, it will need to be situated in the local context (that is, surrounded with cases, models, metaphors, and solutions) where the teaching and learning take place. *i*SPACES' intent is to demonstrate that (1) indigenous knowledge in science lessons, activities, and class projects adds depth and meaning to difficult concepts' and builds communication and respect with the local communities, (2) teaching science in conjunction with local traditional knowledge engenders a sense of place, and renders science "less foreign" to students, and (3) learning to participate in science provides a path for graduates' careers in science by solving common problems.

***i*SPACES' Pedagogical Framework**

The *i*SPACES framework adopts and uses the term "pedagogical framework" from Kim et al. (2007) instead of the more commonly used label "instructional model." Arguably, "instruction" tends to suggest a very teacher-centered environment; whereas "pedagogical" focuses attention on a teacher's craft of encouraging actual learning as students study the relationships among complex science concepts.

As shown in Figure 1, this framework reflects the principles of science, systems, and entrepreneurship and focuses on critical exploration and practical skills that aim to solve real problems encountered in life. The aim is to produce products that improve lives and comfort (Semali & Mehta, 2012). Besides the core courses of physics, chemistry, and biology, the curriculum maintains a conceptual framework that includes a holistic systems approach encompassing (a) Core Science, (b) Practicals, (c) Applications, (d) Conceptualizations, (Ubunifu—Design and Prototyping), (e) Entrepreneurship, and (f) Systems.

As explained elsewhere, ***Ubunifu*** is the overarching concept of the curriculum that binds together the *i*SPACES pedagogical framework (Semali, et al, in press). The assumption is to build a science curriculum that avoids what Tipler (1995) called the "ontological reductionism's concept of science" (p. 294). (See also, Birtel, 1995). The holistic concept of *i*SPACES shuns the idea of a fragmented world or random jigsaw puzzle pieces, both of which assume "separateness" of discreet subjects, factoids, mathematical formulas and equations.

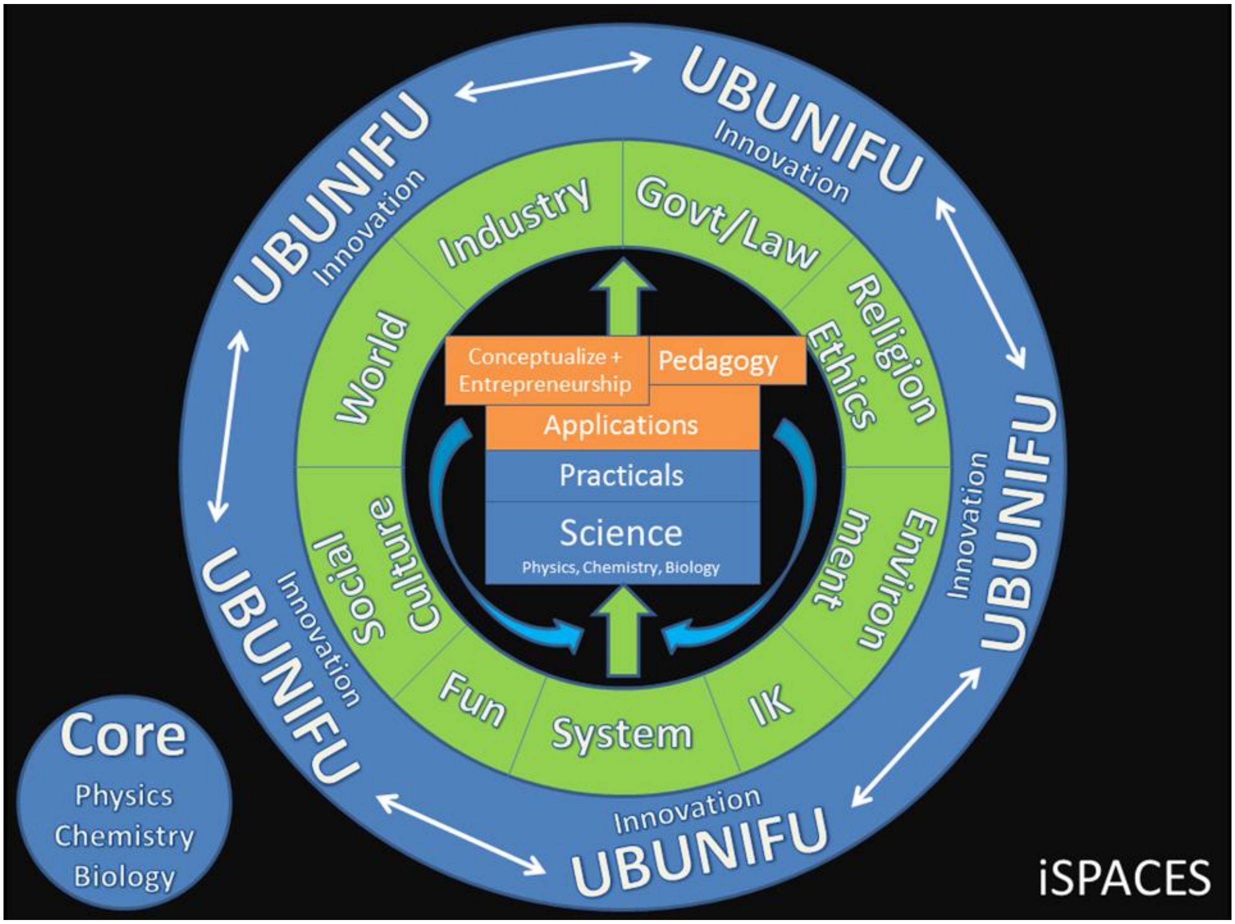


Figure 1: iSPACES Framework
Source: Adapted from Semali & Mehta, 2012, p. 237.

A pedagogical framework that reflects a holistic systemic thinking examines new *assumptions* that are "appropriate to the desired outcomes, realistic, reasonable", and "practical" (Clark, 1997, p. 15). These assumptions have foundations in research, experience, intuition, and insight regarding humans' nature and potential, and, at a more conceptual level, the nature of the universe and humans' relationship to it as observed by research in many fields, including physics, anthropology, psychology, and others. The holistic and systemic thinking in science education is the incentive that motivated the research to develop the *i*SPACES framework. In addition, the curriculum that this framework supports, aims to encompass elements of engaging students' learning and encouraging them to surpass traditional learning strategies of repetition, rote memorization, or focus on standardized tests, but instead emphasize "practical skills," carefully tailored to stimulate generative knowledge, innovation (McRobbie, & Tobin,1997), discovery, and entrepreneurship (Löbler, 2006).

To establish a practical framework, the *i*SPACES project seeks to uncover scenarios of everyday practice that can influence the implementation of theoretically-driven forms of inquiry in science classrooms. Nonetheless, the findings from field study indicated the necessity of both kinds of knowledge for teaching inquiry.

Curriculum Inquiry and Structure

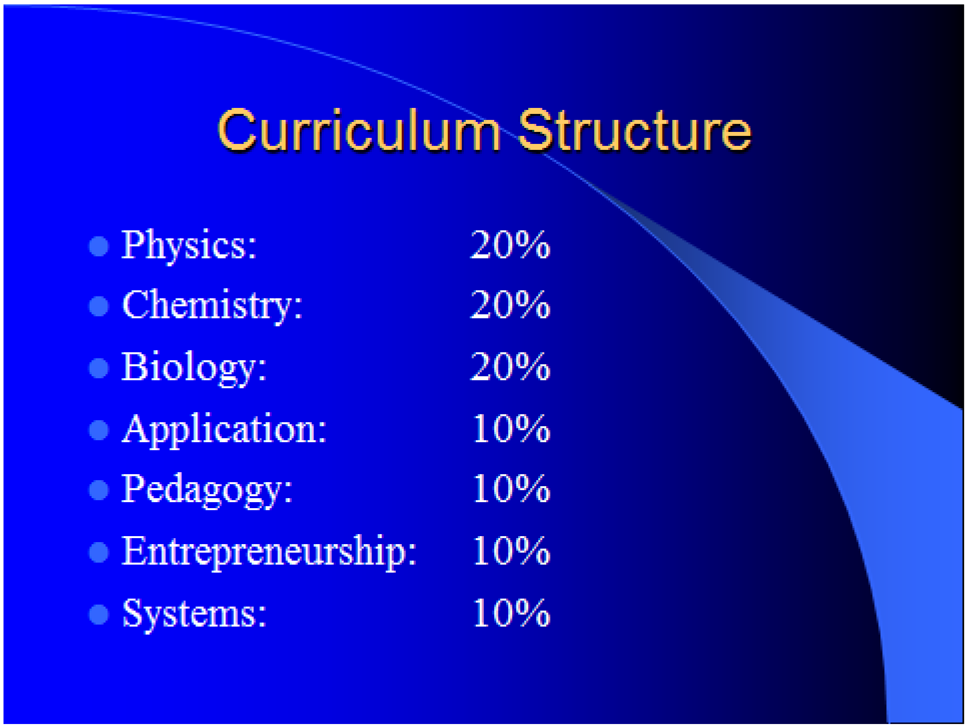
Methods for organizing the curriculum to reflect the *i*SPACES approach relies on the primary objective of *i*SPACES to prepare secondary school science teachers who can train high-school students to transcend "studying" science through memorization to "application" of science and information to address local problems (i.e. designing practical solutions) and adopting a career in science (i.e. entrepreneurial endeavors).

The proposal for this practical educational approach consists of five inter-related phases designed to develop dynamic components that create *i*SPACES (see Figure 1). These interconnected spheres of inquiry or "phases" represent distinguishable aspects of the considered science framework.

As shown in Figure 1, each phase of *i*SPACES represents the principles of (1) science, (2) systems, and (3) entrepreneurship and a focus on critical exploration and practical skills that aim to solve problems arising in daily life. The phases span several lessons with the teacher introducing the various topics during these phases and applying them to the personal cases of students. As illustrated in Figure 1, the small circles within a larger circle and arrows pointing to relationships within and between the entwined components, namely: (1) (society and) culture, (2) (the inhabited planetary) systems, (3) industry, (4) government and law, (5) religion and ethics, (6) environment, (7) and (ecological systems) indigenous knowledge, represent the world knowledge system.

To restructure an existing science curriculum to comply with the *i*SPACES framework, we approximate the teacher balances theoretical materials (about 60 percent) and practical content (40 percent) in the overall curriculum, (See Table 1). The distribution of subsets of the practical content breaks out to: application (10%), pedagogy, (10%), entrepreneurship (10%) and systems (10%). Undoubtedly the teacher remains the important and necessary link between home and school. The proposed framework envisages a teacher's task to be restructuring the existing science curriculum and rethinking teaching of physics, chemistry and biology (PCB) to overcome students' cognitive conflicts between their everyday lives and the world of academic science.

Table 1: Curriculum Structure



Curriculum Structure

Physics:	20%
Chemistry:	20%
Biology:	20%
Application:	10%
Pedagogy:	10%
Entrepreneurship:	10%
Systems:	10%

The hypothetical science teacher introduces the various topics in a subject during the phases and applies them to students' personal cases. The ultimate aim of the lessons is to produce products or solutions, improve lives and comfort and enhance the wellbeing of people (Semali & Mehta, 2012). Teachers encourage students to reflect on their own experiences as science learners and compare those new experiences to the ways they interact with the world's knowledge system. Some basic questions (see Clark, 1997) that encompass the integrative parts include: (1) How does the universe work? (2) How do people interact with the physical environment? (3) As citizens of the universe, how do experiences affect decisions and choices? (4) How has the past shaped the present, and how will the present shape the future?

Conclusion

This paper discussed ways to restructure an existing curriculum and enable teachers to rethink the methodologies for teaching physics, chemistry, and biology. The paper demonstrated how students from diverse backgrounds—social, cultural, or ethnic—stand to benefit from the proposed *iSPACES* framework that attempts to overcome students' cognitive conflicts between their everyday world and the world of academic science. The *iSPACES* framework showcased inter-connected spheres of knowledge and showed how the principles of science, systems and entrepreneurship can be designed to combine critical exploration and practical skills that aim to solve real problems encountered in life. Elsewhere, we have provided examples of how to design a chemistry lesson with the ultimate aim of producing and marketing a product, "soap" (Semali & Mehta, 2012; Semali et al., in press). Soap was considered an appropriate example of combining science and the production of a product that addresses a health related issue—

hygiene. The example of soap is one among many ways a teacher can turn around a traditional curriculum to become practical and expose students to the benefits of linking classroom science to practical uses.

The lessons drawn from this study indicate, first, that *i*SPACES can leverage STEM science principles to provide workable solutions to overcome everyday problems associated with poverty, famine, and disease in culturally responsive pedagogy. Second, the role of the teacher in implementing the *i*SPACES framework to rethink and to restructure a culturally responsive secondary science curriculum in Tanzania is critical and cannot be overlooked. Equally, contributions of all stakeholders, including contributions from industry, parents, teachers, curriculum planners and professional development experts are essential to make iSPACES work.

Third, the study showed that for the iSPACES framework to produce the anticipated outcomes, teachers must recognize that culturally responsive pedagogy facilitates and supports the achievement of all students after identifying the strengths students bring to school, and nurturing, and using those strengths to promote student achievement. Arguably, many challenges lie ahead as teachers and students implement the *i*SPACES experiment in STEM science. In spite of looming logistical, academic and fiscal challenges, teachers and students must commit to try. The divergent interests of stakeholders identified in this project did not prevent them from coming to consensus on *i*SPACES. By the same token, school principals and other education leaders committed to science education reform must encourage these experiments and reward teachers who dare to try. After all, science is about experimenting. Difficult as it may seem to fathom the massive effort required to bring all actors involved in the school science reform in Tanzania or to engage them in lockstep to embrace the *i*SPACES experiment, it is important to note that opportunities exist for small and inexpensive experiments to link everyday practices in food/nutrition (chemistry), farm implements (physics), and animal husbandry (biology/animal sciences) that can be done in the current science national curricula.

Fourth, the *i*SPACES framework identified teaching personnel as the most important resource in education reform. Bybee (1993) reminded educational planners "that the decisive component in reforming science education is the classroom teacher . . . unless classroom teachers move beyond the status quo in science teaching; the reform will falter and eventually fail" (p. 144). Science education is one of the areas that need to undergo much needed reform. In order to avoid the pitfalls of past reforms, some analysts are calling for new methods for addressing change in schools and clearly, classroom teachers should be the focus of restructuring (Duschl, 1990; Brown, 1992; Meece, et al., 2006).

Another aspect not extensively addressed in the literature of Tanzania's science education is teachers' beliefs, which have been suggested to be the best indicators of the individual's decisions throughout life (Bandura, 1986). Yet, beliefs often disguised as a variety of aliases, include attitudes, values, judgments, opinions, ideologies, perceptions, conceptions, conceptual systems, dispositions, theories, etc., (Pajares, 1992). Pajares argues that clusters of beliefs form attitudes and attitudes, in turn, become action agendas; thus, people act upon what they believe. The connections among clusters of beliefs create an individual's values that guide life and ultimately determine behavior (Ajzen, 1985). Since teachers are social agents and possess beliefs regarding professional practice, and since their beliefs may impact their actions, teachers' beliefs may be crucial agents of change in paving the way to reform science education. While actual studies regarding the impact of teacher beliefs on the implementation of educational reform policies are scant, actual studies of teachers' beliefs regarding education for teaching science are almost non-existent in Tanzania. Future studies need to address this gap.

In sum, therefore, assuming that the teacher is instrumental to the success or failure of implementing any curricular innovation in practice (Mitchener & Anderson, 1989), school and science curriculum reforms must have consonance with the realities of programs for educating science teachers (Shymansky & Kyle, 1992). Any educational reform is likely to fail, if it cannot rely on a suitably prepared teaching profession, ready to execute educational reforms. For this reason, we commend private universities in Tanzania for exploring this important but neglected area that is much in need of reform and for prioritizing it in the design of new baccalaureate degree programs.

References

Ajzen I. (1985) From intentions to actions: A theory of planned behavior, In J. Kuhl and J. Beckmann (Eds.), *Action-control: From cognition to behavior* (pp. 11-19). Heidelberg, Germany: Springer.

Bandura, A. (1986). *Social Foundations of Thought and Action: A Social Cognitive Theory*. Englewood Cliffs, NJ: Prentice-Hall.

Birtel, F. T. (1995). Contributions of Tipler's Omega Point Theory. *Zygon*, 30(2), 315-327.

Brown, A. L. (1992). Designing experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *The Journal of the Learning Sciences, 2*(2), 141-178.

Bybee, R. (1993). *Achieving scientific literacy: from purposes to practices.* New York, NY: Teachers College Press.

Cavicchi, E., Chiu, S. M., & McDonnell, F. (2009). Introductory paper on critical explorations in teaching art, science, and teacher education. *The New Educator, 5*(3), 189-204.

Clark, E. (1997). *Designing and implementing an integrated curriculum: A student-centered approach.* Brandon, VT: Holistic Education Press.

Dewey, J. (1938). *Experience and education*. New York: Macmillan.

Duckworth, E. (2005). Critical exploration in the classroom. *The New Educator, 1*(4), 257-272.

Duschl, R. A. (1990). *Restructuring science education: The importance of theories and their development*. New York: Teachers College Press.

Gay, G. (2000). *Culturally Responsive Teaching: Theory, Research, & Practice*. New York: Teachers College Press.

Gay, G. (2002). Preparing for culturally responsive teaching. *Journal of Teacher Education, 53*(2), 106-116.

Gee, J. (1996). *Social linguistics and literacies: Ideology in discourses* (2nd edition). London: Falmer.

Glynn, T., Cowie, B., Otrel-Cass, K., & Macfarlane, A. (2010). Culturally Responsive Pedagogy: Connecting New Zealand Teachers of Science with Their Maori Students. *Australian Journal of Indigenous Education, 39*, 118-127.

Heraldo V. Richards, H. V., Brown, A. B., & Forde, T. B. (2004). *Addressing Diversity in Schools: Culturally Responsive Pedagogy.* Nashville: Houghton Mifflin Publishing. http://www.ibrarian.net/navon/page.jsp?

Hudson, P., & Skamp, K. (2002). Mentoring pre-service teachers of primary science. *Electronic Journal of Science Education, 7*(1), 1-29.

Kim, M. C., Hannafin, M. J., & Bryan, L. A. (2007). Technology-enhanced inquiry tools in science education: An emerging pedagogical framework for classroom practice. *Science Education*, *91*(6), 1010-1030.

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development (Vol. 1)*. Englewood Cliffs, NJ: Prentice-Hall.

Ladson-Billings, G. (1995). Toward a Theory of Culturally Relevant Pedagogy. *American Educational Research Journal, 32*(3), 465-491.

Laughter, J. C., & Adams, A. D. (2012). Culturally Relevant Science Teaching in Middle School. *Urban Education, 47*(6), 1106-1134.

Lewin, K. (1936). Principles of topological psychology. New York: McGraw-Hill.

Löbler, H., (2006). Learning entrepreneurship from a constructivist perspective. *Technology Analysis Strategic Management, 18*(1), 39–56.

McRobbie, C., & Tobin, K. (1997). A social constructivist perspective on learning environments. *International Journal of Science Education, 19*(2), 193–208.

Meece, J., Anderman, E., & Anderman, L. (2006). Classroom goal structure, student motivation, and academic achievement. *Annual Review of Psychology, 57*, 487-503.

Mitchener, C. P., & Anderson, R. D. (1989). Teachers' perspective: Developing and implementing an STS curriculum. *Journal of Research in Science Teaching, 26*(4), 351-369.

Moje, E. B. (2007). Youth literacies, identities, and cultures in and out of school. *Handbook of Research in Teaching the Visual and Communicative Arts*, 1-36. Retrieved: November 14, 2009.

Moll, L. (1992). Funds of knowledge for teaching: Using a qualitative approach to connect homes and classrooms. *Theory into Practice, 31*(2), 132-141.

Moll, L., Amanti, C., Neff, D., & Gonzalez, N. (2005). Funds of knowledge for teaching: Using a qualitative approach to connect homes and classrooms. In González, N., Moll, L., & Amanti, A. (Eds.). (2005). *Funds of knowledge: Theorizing practices in households, communities, and classrooms.* Mahwah, NJ: Erlbaum, (pp. 29-46).

Nyerere, J. K. (1968). Education for self-Reliance. In: *Freedom and socialism/Uhuru na ujamaa: Essays on socialism*. 278-290. New York: Oxford University Press.

Pajares, M. F. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. *Review of educational research, 62*(3), 307-332.

Piaget, J. (1957). *Construction of reality in the child*. London: Routledge & Kegan Paul.

Semali, L. & Mehta, K. (2012). Science education in Tanzania: Challenges and policy responses. *International Journal of Educational Research 53*, 225–239.

Semali, L., Hristova, A., & Owiny, S. (in press). Integrating Ubunifu, Informal Science and Community Innovations in Science Classrooms in East Africa: A Comparative Case Study. *International Journal of Science Education.*

Semali, L. (1999). Community as classroom. *International Review of Education.* 45(3/4), 305-319.

Shymansky, J. A., & Kyle, W. C. (1992). Establishing a research agenda: Critical issues of science curriculum reform. *Journal of Research in Science Teaching, 29*(8), 749-778.

Stoecker, R. (2013). *Research methods for community change: A project-based approach.* Thousand Oaks, CA: Sage.

Tipler, F. J. (1995). *Critical Notice: The Physics of Immortality: Modern Cosmology, God and the Resurrection of the Dead.* London: Macmillan.

Villegas, A. M., & Lucas, T. (2002). Preparing culturally responsive teachers: Rethinking the curriculum. *Journal of Teacher Education, 53*(1), 20-32.