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GLOBAL CHANGES IN SCIENCE EDUCATION (SE) AND THEIR IMPLICATIONS FOR SECONDARY SCHOOL SCIENCE TEACHING AND LEARNING IN DEVELOPING COUNTRIES

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Abstract:
Changes in today's modern science education (SE) are both rapid and intricate, bringing both significant challenges and new opportunities in the field of science education. Despite their complexity, they appear to serve as a wake-up call for all science stakeholders in the world including Tanzaniato start thinking about the changes can be appropriately addressed and accommodated in present school curriculum. However, along with this need, it appears that there is little understanding on what exactly these changes are and their impact in the SE practice. This review paper intends to develop an understanding of the nature of these changes; ascertaining their implications in the practice of SE in secondary schools and identifying the way forward to address them. This includes analyzing how SE can be appropriately organized to address such changes.

Keywords: modern science education, relevant science education, functional science education.

Introduction

The development of SE around the world has accelerated the pace of "*science-driven change*" in modern societies, allowing science as an educational subject to become more important than ever before (Lederman, 2008b). Lederman (2008) argues that:

> *"We have arrived at a point in history where there must be a major increase in the capability of ordinary people to cope with the scientific and technological culture that is shaping their lives and the lives of their children (p. i)."*

With such an aspiration, improving SE has become of paramount importance in determining a country's scientific status and its socio-economic power in today's open economies. The desire to develop SE is clear and, in many countries, there is an evidence of several opportunities to ensure that quality, relevant and sustainable SE is provided for every student.

A review of the literature establishes that efforts to improve SE in most African secondary schools since the 1980's have been impacted by a number of global challenges (Ogunmade, 2005; Ogunniyi, 1986) which appear to have greatly influenced SE practices in the schools. These challenges include changes related to: Science as a discipline itself, the evolution of societal needs, new developments in technology, scientific innovations, changes in the purposes of SE, the intensification of globalization, changes in new theories of learning, changing labour force demands and the evolution of the market forces in science careers. These changes seem to have altered global educational needs and thereby challenging African schools' to transform their structures and processes of education towards more relevant issues for the learners and society at large to the functional members of the society (Stewart, 2010; Wilmarth, 2010). Such changes have also led to a mismatch between the knowledge and skills that the schools offer, and the competencies that school graduates need for them to face their futures confidently.

Most developing countries face many of these challenges, the result of which have increased the need to redefine SE practices; to make it more functional for learners and more effective in catering for their needs, especially the needs of those learners who choose to pursue the formal study of science beyond secondary education (Osaki, Hosea & Ottevanger, 2004, Ogumnmade, 2004). Another pressure on SE is about the need to address the public outcry from developing countries including parents, employers, and the private sector, who claim that there is a huge difference between the kind of graduates they expect and those being produced by schools, colleges and universities with science specialisations.

Additionally there have been a number of important reports related to SE in Africa over the past two decades, including those of Ogunniyi (1986), Osaki et al (2004) and Ogunmade (2005) that have strongly identified the need to improve SE in schools. Their contributions to African SE literature and their recommendations have made a major contribution towards better understanding the status of SE in the region. The Intention of this review paper is to build on previous studies in SE by developing an understanding of different global changes in SE and their impact in the current practice of SE in secondary schools found in developing countries. This intention is built around making SE relevant, functional and sustainable and with the ability to connect the

school SE experiences to students' daily lives as well as enabling them to play a more functional role in society (Diut & Treagust, 2003).

The aim of study

With the intention of making SE relevant and functional to the learners in developing countries; this review paper, intended to examine the nature of global changes in SE and their impacts to the current SE practices in the developing countries. Specifically the review intended to:

a) Develop an understanding about several changes in SE.
b) Ascertain the implications of these changes in the practice of SE in schools.
c) Identify the way forward to address the present global changes

It is not the intentions of this paper; however, to identify dogmas to be followed, but rather provide the possible breakthroughs to be adapted as different countries prepare themselves towards addressing current and future global science related challenges. This initiative is similar to the desire of developing relevant SE systems in developing countries, the initiative which involves the process of aligning the SE to the values, needs and expectations of society. The paper responds to the need of SE system being able to inform policy, citizens and politicians objectively about how the global changes in SE can be appropriately addressed. In the following sections, the paper briefly addresses the methodology employed in this paper.

Methodology

The methodology adopted by this review paper is a mixed form of data collecting methods including: literature reviews, desk research, web searches, and analysis of publicly available databases in the field of SE. It also includes governmental and nongovernmental reports, policies, and other initiatives related to new developments and changes in SE. The methodology was set out to examine the experiences from national and international literature and the evidence from empirical studies about the global changes and their implications to the current and future SE practices in developing countries. The plan of analysis centered at reviewing only those academic research, reports and journal articles which attempted to describe the nature of various global changes in SE. It is envisaged that the discussion from this article will help in preparing the developing countries to address the challenges related to the topic more effectively. The next sub section outlines the need for discussion about this topic in developing countries.

The global changes in SE: Why should this be an important topic for discussion in developing countries?

In the era of science and technology, the developing countries would need to be knowledgeable in science to prosper in a complex and global society (Bull, Gilbert, Barwick, Hipkins, & Baker, (2010). This ambition is underpinned by the belief that scientifically literate citizenry is needed to make informed decisions about the nation's health, technological developments, agricultural mechanisation, nutrition, environmental conservation and food preservation which all depend upon community literacy regarding scientific principles and concepts (UNESCO, 2008).

There are a number of issues related to SE in the developing countries, which appear to be of great concern. These include:

a) The participation gap in SE. There has been a persisting participation gap in SE in formal, non-formal and informal settings, across regions, cultures, gender and other several disadvantaged groups (such as women, learners from rural areas, and learners from poor socio-economic status) in most African countries (Anamuah-Mensah, Mereku, & Asabere-Ameyaw, 2004). This situation not only blocks the full involvement in society of all citizens and talents in SE but also limits their contribution to this field.

b) The lack of interest in science careers among many students. This is demonstrated by the situation whereby many students have been turning away from science studies and related careers. The issue of developing interest in SE is essential in meeting the demand for well-prepared graduates (at all levels) and researchers, necessary for our knowledge and innovation-intensive societies and economies (Osaki, 2007; Osborne & Dillon, 2008).

c) The poor schooling environment. This includes the lack of competent teachers who are able to inspire their students, inappropriate professional development training among teachers as well as an absence of interesting and motivating curricula (Lederman, 2008; Osaki et al., 2004). There is also a lack of clear shared standards for SE that would help all involved in the system to set and achieve goals (Reddy, 2006). As a result, too many students conclude early in their education that science subjects are too difficult, unfavorable, or boring and without future, and in most cases the training in SE leaves them inadequately prepared to face challenges in their futures.

d) Lack of a science capable community. Despite the fact that science is important, even for people who are not planning to become engineers, mathematicians or scientists (Holbrook, 2010; Osborne & Dillon, 2008), most of developing countries arguably lack a science capable community. An increasing number of jobs today draw on at least some knowledge or skill from science fields and every occupation has the potential to be

transformed by scientific and technological advances. This situation presents the need for citizens in the developing countries to have an understanding of science and technology, the knowledge that could help them to make informed decisions about issues facing their nations and the planet at large.

e) Lack of science-proficient workforce. The nation's ability to solve problems and achieve economic growth seems to largely depend on cultivating a future workforce that is science literate. This need is urgent in developing countries because the region's economy needs a large and an increasing supply of workers who can use scientific knowledge and skills in their jobs to fuel scientific discoveries, innovations and entrepreneurship (Ogunmade, 2005).

f) Lack of future science experts. The developing countries need a steady stream of the best science researchers and innovators and a large pool of science experts with the knowledge and desire to advance science and technology in the country (Bybee, & Fuchs, 2006; 2010). Science experts can play an important role in providing knowledge that serves a nation in various socio-economic and cultural issues such as security, mining, communication and transportation. They can also help to develop the new ideas and inventions necessary for the country's technological development as well as inspiring and mentoring new generations of scientists, engineers and mathematicians. This group of professionals is likely to contribute immensely to economic growth, technological progress as well as developments in high-tech industries, medical research centres and engineering firms. More importantly, they also help in retaining these advantages by building a strong science expertise.

g) *Some limitations related to the way SE is practiced in schools*. Despite clear and well-focused intent to strengthen the scientific knowledge base among the public, experiences reveal that instead of making sure that science students are provided with quality SE experiences, practices in developing countries still seem to be limited to the following: Preparation of students for examinations at the expense of developing conceptual knowledge about science, the absence of practical work experience in some of schools, a situation which limits the students from developing procedural knowledge in science and the absence of clear delineation about the nature of science and its relationship with other disciplines (Hipkins et al, 2002; Tytler, 2007).

h) Extensive demand of knowledge to use digital technology: The demand for knowledge in digital technologies is intensely and extensively throughout all aspects of contemporary life. From children entering school now to the old generation retiring in science careers altogether require the knowledge of digital technology.

i) Unevenness in basic science literacy across the entire region. The literacy in basic science is necessary to ensure a rigorous understanding and use of scientific knowledge

in decision-making, particularly in domains such as health, the environment, food, energy and consumption. The evidence from developing countries shows that the region is not doing well in terms of how science can be made useful to solve both the contextual and global science related challenges.

These issues are complex and multi-factorial, but the good news is that there is an opportunity to create long-term added value through enhanced scrutiny on how these global changes and their related challenges in SE can be handled and sustainably addressed through the schooling system. The developments of these challenges have quickened not only the need to do something worthwhile in SE but also have created the necessity to connect SE to the daily societal issues. These challenges also are placing new demands on the governments, educational institutions, businesses and civil society organizations to meet the evolving needs of society and the workplace. The failure to address these demands is similar to straining the existing resources, including: energy, environment, food, water, housing, communication, social cohesion and culture. Looking at these concerns and considering how influential on contemporary SE they have been, it is considered important to write this review paper, especially at this time when SE has become a common topic for most national media, public talks and policy debates. Investing efforts to understand the global changes in SE with the intention of addressing them appears to be an inevitable option.

How SE practices have changed over time?

SE practices worldwide show that the structure of SE has remained relatively unchanged for the last half-century, and also that its practice has been similar worldwide (Symington & Tytler, 2005; Tytler, 2007). In developing countries, the SE has always been provided through distinct disciplinary strands, such as biology, chemistry, engineering science, and physics; the strands which are operationalized as relatively constant components of SE. Research evidence towards the end of twentieth century has revealed that the practice of SE has concentrated in the developing literacy in three strands of SE which include: developing conceptual knowledge (content), developing procedural knowledge (how to do science) and the nature of science (learning about science). However, the current focus of SE in developing countries seems to be centre at three basic concerns; two of these have traditionally been framed as more important than the third.

Historically, questions about the nature of science have been framed as less relevant, however currently, and internationally, curricula are giving the nature of science a bigger emphasis (Bull, Gilbert, Barwick, Hipkins& Baker, 2010). This focus is

one which is still shaping most science classrooms today. Both UNICEF and UNESCO also recognize five major emphases in today's education (SE in this case) which include: acquisition of survival skills; supporting the objectives of peace, citizenship and security; development of cognitive, emotional and creative capacities among learners; promoting equality, and seeking to pass global and local cultural values down to future generations (UNICEF, 2009; UNESCO, 2008).

Underpinning the view by UNESCO and UNICEF is the economic, socio-cultural, political and technological developments in today's world, which are increasingly described as shaped and directed by science (Osborne & Dillon, 2008). This means that most socio-political, economical, scientific and technological developments in today's world depend on not only the quality but also relevance, functionalism and context responsiveness of SE that each country is able to provide to the current and future generations of its citizens.

Today the education processes and reforms, especially those related to SE, are challenged by the constant changes in the education environment, world-wide competition, globalisation of markets, high customer demands, changing educational stakeholders, and the long-lasting impacts of information technology, global economic instability, and strong demands for economic and social development (Bull, Gilbert, Barwick, Hipkins & Baker, 2010). The shift towards increased attention in SE appears to be a popular song of most education systems in developing countries. This is probably because the high quality SE systems have been identified as central enablers for individual countries and learners being able to respond appropriately to a variety of social and cultural challenges (Education Queensland, 2004; Holt, 2000; Kubow & Fossum, 2003). The emergence of these new developments reveals a changing focus regarding SE practice.

New trends and changes in SE

The current SE appears to be driven by complex and conflicting variables that feature rapidly growing transformations marked by new discoveries and progress in all spheres of human activity, including economic, social, cultural and political (Bull et al, 2010; OECD-GSF, 2006; 2007). One notable consequence of these transformations is the pressure to redefine the school SE practices to enable citizens to deal with the challenges in the modern world.

Drawing from this ambition it appears inevitable for most, if not all, developing countries to make SE contextually relevant and functional for students in solving the challenges they encounter in life (OECD-GSF, 2006; Ogunniyi, 1986). Despite the

outlined need of these countries, studies argue that the SE provided in schools in most developing countries need to be reframed so as to offer the knowledge and skills needed for the scientific and technological development of those countries (Ogunniyi, 1986; OECD-GSF, 2006; Osaki, et al., 2004). As a result of this requirement, both structural and procedural reforms of SE have been unavoidable.

In this modern era of information, evidence shows some new emphases and thoughts in the practice of SE. For instance, there is increasing emphasis on the '*processes*' versus the *'products'* of science, an emphasis on better linking science with its technological and social implications (as opposed to the current emphasis on inquiry as a predominant feature of school science), an emphasis on context and a supportive learning environments (as opposed to established approaches to teaching that favoured universalisation of science content and pedagogy), an emphasis of technological inventions and scientific discoveries (as opposed to dwelling on consumption of other's technology and scientific discoveries) (Bull et al., 2010). These newly emerging areas of emphasis appear to challenge the structure and processes of SE in today's schools.

According to Bull et al. (2010) and Tytler (2007), the changing conditions and emphases in SE demand some modifications on how SE is planned, practiced and monitored in today's schools. These changes include:

1. *The changing practice of science from the traditional role of the scientist.* This includes shifting from viewing science as an individually controlled pursuit to viewing it as commercial, multi-disciplinary, and technologically linked to bigger projects, which have impact on the larger community (Goodrum, Hackling, & Rennie, 2001).
2. Increasing emphasis on providing opportunities for scientific discussion, extended scientific inquiries and debate among students versus presenting scientific knowledge through lecture, text, demonstration, and rigidly orienting the learners towards acquisition of information
3. Changing focus of science from focusing on student acquisition of discrete information towards looking at science a body of knowledge to be studied so that it can inspire citizens to use evidence-based reasoning for decision making; develop confidence, knowledge and skills among the citizens so that they participate actively in an increasingly complex scientific and technological world; as well as developing analytical and critical thinking that are necessary to empower citizens to lead personally fulfilling, socially responsible and professionally-engaged lives;
4. *The changing practice on the way the public engages with and responds to science and its products*. The public has shifted from viewing science as a purely academic

discipline to viewing it as a necessary undertaking for managing resources and mastering socio-economic problems (Aikenhead, 2001; 2006).

5. *The increasing attacks on science as a body of knowledge*. Modern science is increasingly being attacked as being dogmatic, universalistic and for its claim as being humanity's most powerful knowledge, more 'truthful' and functional than any of the others (Symington & Tytler, 2005).
6. *The increasing knowledge explosion*. New theories are overthrowing the old ones, new science information is being assimilated into old, unverifiable hypotheses are being discarded, hypotheses supported by evidence are being treated with greater confidence, and continuously rechecking scientific results, while tentative theories are published in scientific publications. All this must be assimilated by SE (Aikenhead, 2006; Tytler, 2007).
7. *The changing nature of learning science*. This is exemplified by a shifting emphasis from teacher-centred and content-centred learning to student-centred learning. This shift is promising to reduce the unnecessary difficulty of school science learning to an interesting discipline of study enjoyed by all (Fletcher, 2003).
8. *The changing audience for science education.* This is marked by a shifting emphasis from science being only for a few selected people to science being open to all. Practically, this is represented by making science compulsory for all up to high school, including those not destined for post-training in SE careers. While "*science for all*" is still contestable, this change has led to a need for SE practices to be redefined to accommodate diverse student populations with a wide range of responses towards what is essential and worthy learning in science (Fensham, 2011).
9. *Changing focus from science knowledge consumption to knowledge creation and amendment.* This focus marks the shifting emphasis of scientists from being consumers of others knowledge to being knowledge creators, developers and amenders. This emphasis brings the importance of enabling scientists to become innovators, technology inventors, and scientific architects. This shift of practices challenges the developing countries which for a long time been consumers of western science and technological discoveries to start rethinking on how they can take lead of developing relevant and contextually functional SE.

Given such a global evidence of in the practice of SE, and the changing needs of society, there is an urgent need to act promptly in preparation on how such challenges can be appropriately addressed in the schooling system. This initiative is likely to help not only to improve the relevance of the SE offered in light of the existing challenges but also it is likely to improve the motivation and interest of students to choose science

studies and their related careers as their future professions. The global changes highlighted so far seem to put pressure on today's SE systems all over the world to start thinking of developing programs or measures which take advantage of the present science workforce, and the remarkable opportunity offered by the internet for global improvement of SE in terms of its relevance to the society.

While there is evidence of bright spots in developed world where innovative approaches seem to be having some success in the practice of SE; the evidence from developing countries still show a state of inadequacy in SE. Although researchers' efforts in developing countries have made progress in addressing the challenges related to global changes in SE, these efforts seem to be not enough, the governments can also be blamed for showing little commitments in improving SE. This situation has ultimately led to the weak scientific and technological foundations of SE in most of the countries (Fensham, 2004). It is perhaps surprising that in this global era, where SE holds the first priority in socio-economic development, most developing countries still embraces weak SE frameworks which have failed to capture critical issues in SE that could sustain the countries' desires to provide functional and relevant SE to the public.

Unlike the poor trend of SE in most developing countries, evidence also shows that there has been growing demand for the public to engage with science and applications of science in the form of rapidly developing technologies such as computers and mobile phones (Hamilton et al., 2010). However, SE practices in schools are still focused on the preparation of students who know and "*can consume*" large amounts of scientific information, but are unable to develop the creative and innovative skills necessary for their survival nor are they able to use the learnt knowledge to address and possibly solve science related social issues (BouJaoude, 2006). Most SE systems in the developing countries are blamed for their failure to develop individual learners into sound, effective citizens and self-dependent individuals who are able to respond to the contextual pressures and overcome the existing challenges**.**

Implication of global changes in the practice of SE

As modern civilization has developed, there has been a need for regular refocusing of SE in every country in the world (Osborne & Dillon, 2008). In the context of developing countries there have been a variety of projects initiated to improve the quality of SE, all of which have focused on improving the way SE is enacted in schools (Fensham, 2009; Osaki et al 2004). In many situations, however, these projects had been limited by scope and duration, contextual and cultural limitations, with dilemmas in what to address

and who to target. As a result, these projects have not impacted positively in the public literacy in SE (Osaki, 2007).

In the pursuit of new visions and aims at different levels of education the need for life-long learning, global networking, international outlook and the use of information and technological power has arisen to ensure that the aims, content, practices and outcomes of education are relevant and functional for present and future generations (UNICEF, 2009; UNESCO, 2005). Along with new development, there are some challenges which greatly impede the efficient practice of SE. One of these challenges is a failure to develop strong scientific community and skilled manpower in the field (Hodson, 2014). According to Bybee (2006) and Osaki et al (2004), the development of scientifically skilled manpower is only possible when the provision of relevant SE is a central concern. This situation explains why various strategies are being put in place in developing countries to ensure their citizens are scientifically literate (World Bank, 2011).

Achieving public scientific literacy and be able to benefit from a well performing SE system, it is no longer helpful to think about improving SE practice merely in terms of maintaining standards and closing the eyes not see what goes on out there (Fensham, 2004). Instead, Srikanthan and Dalrymple, (2003) suggest taking a developmental approach by pragmatists who articulate on the need to refocus SE based the existing challenges and promising practices. This approach focuses on building a direct connection between the SE offered in schools to the realities out there. The developmental approach would exist in the form of multi-involvement practices, where policy makers and planners, educators, communities, parents, teachers, students and other stakeholders in educational decisions are involved in a strategy for creating relevance, ownership and accountability for their children's education (Delputte, 2013).

The implication drawn from these emerging changes in SE indicates that there is a need to readdress the way SE is viewed and enacted, particularly so that it is made relevant and functional for the public (Aikenhead, 2001). Achieving this goal demands not only a clear and focused change to the way SE is planned, practiced, evaluated and monitored but also a reflective approach of what is happening in the world, and what could be the best option to adapt. In such a process Tytler (2007) suggests for the necessity to prioritize the following in the practice of SE : Ascertaining the sort of knowledge worth knowing and its ability to serve the future needs of students as responsible citizens; accepting that SE ends are acknowledged and adapted in informing the practice; allowing that a variety of voices and interests to be included when charting a way forward for relevant SE, and acknowledging the set of

circumstances controlling the implementation of the whole process of providing quality SE in schools.

Moreover the current situation of SE in developing countries, also suggest that greater attention should be given towards:

- Promoting appropriate science research and innovation whose outcomes are likely to help in addressing the global challenges in SE.
- Connecting innovation and SE strategies, at local, regional, national, and international levels, taking into account societal needs and global developments.
- Involvement of international partners in addressing the critical issues in SE and the underlying consequences.
- Active and direct involvement of the society in science research and innovation projects.

The new development in today's SE also appear to suggest for concerted efforts in building curiosity about the world around us, learning to act and think like a scientist and understanding the nature of science, all of which provide a solid foundation for future success. It is only by relevant and functional SE that developing countries can build upon everyday experiences and thus being able to develop strong relationship between what is taught in the classroom and the world around them. This is similar to shifting the focus of SE from learning discrete scientific facts to understanding how to apply science learning to new situations. This initiative would help in transforming knowledge into usable forms which in turn could help in producing positive attitudes towards science – a vital requirement for active, responsible citizenship.

Collaboration between science educationalists, formal, non-formal and informal educational providers, research centres, enterprise, industry, civil society, and other professionals, appear to be another necessary aspect in an attempt to address critical global issues in SE. This initiative is important in that it is likely to ensure meaningful engagement of all societal actors in science and thus increasing the uptake of science studies and science-based careers; help in increasing interest in science and science-careers and offer exciting ways to address critical issues in SE.

Looking at situation of the fast changing citizens' needs and the multi-facetted nature of the task to address the global challenges in SE; it is strongly recommended in this paper that the individual countries in the developing countries need to bring together key actors from within the states to initiate a participatory consultation and dialogue process across the region on the promising actions for successful discussion about the global challenges in SE. This is an important initiative for a collective vision and shared sense of accountability, responsibility and innovation by all society's stakeholders from educational institutions (such as schools, colleges, universities),

business enterprises, and other small groups (such as families, teachers and students), to the public and civil society organizations. Basically the efforts to address the global challenges in SE should involve all members of the developing countries, at local, regional, national level, acting together in a coherent and integrated way.

Conclusion

As the world becomes more inter-connected and globally competitive in all facets of life, often these changes appear to come hand in hand with complex dynamics that happen to influence the educational practice (SE in this particular case). There is substantial scientific agreement about the occurrence, causes, and consequences of global change in the practice of SE. Yet due to the inherent complexity of the topic, the social controversies, confusion and doubt often persist. As such there appears to be a need of developing a clear understanding of the nature of these changes, the worthiness of being addressed and their notable impacts in the practice of SE in developing countries. The ability to address this need depends on the current best scientific understanding of the topic.

The paper presents the need of creating awareness among the public about SE dynamics, so that the public can participate actively and responsibly in making informed decision about several SE issues that directly impact their lives. The paper provides not only the direction concerning increasing the relevance of SE in developing countries but also identifies the challenges resulted from the global changes and how these challenges can be effectively addressed. It is also evident in the paper that for developing countries to achieve the ambitious goal of providing relevant, functional and context responsive SE there is a need for all citizens to have a better understanding of SE and its related dynamics if they are to participate actively and responsibly in science-informed decision-making and knowledge-based innovation. This initiative should be focused at making sure that the SE provided in schools is made more responsive to the needs and ambitions of society and reflect its values.

Furthermore, the paper recognizes that there is a need to develop the direct connection between the SE delivered and society needs and expectation. This initiative is important in that clear articulation of the global challenges in SE is likely to enable to be able to make scientifically informed decisions about the consequences of such changes. The importance of understanding such global changes in SE and being at good to position to address them provides the essential foundation towards avoiding the negative impacts that these changes have on the relevance of SE. I believe that the paper makes a substantive contribution to the policy debate in the developing countries on

how best the global changes in the practice of SE can be addressed but also outlines necessity of creating a better transformative connection between the SE provided and society needs and expectations. However this is possible only if joint initiatives are established to create a regional and national-wide response and dialogue processes to effectively respond to critical issues in SE that have been so rampantly disadvantageous in the efforts to develop functional and context responsive SE in developing countries.

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