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CHAPTER 8

The role of Indigenous Knowledge in *STEM* Education: An African perspective

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Abstract

It is generally appreciated that a strong correlation exists between the economic prosperity of a nation and the provision of quality Science, Technology, Engineering and Mathematics (STEM) education. Countries at the forefront of scientific and technological innovation have enviable and robust economies and their citizens lead comfortable and decent lives. Unfortunately, the same cannot be said of the vast majority of the African continent's nations and citizens. Africa is a continent besieged with endless challenges that include incessant conflicts, famine and poor access to basic amenities such as clean water and electricity. In addition, Africa lags behind in as far as the provision of quality STEM education is concerned. The main aim of the study is to formulate a STEM model that advances the role indigenous knowledge should play in the teaching and learning of STEM subjects in an African context. To achieve the main aim, this study reviews and considers

the role indigenous knowledge plays in the offering of quality STEM education in an African context. The study also interrogates existing STEM models that inherently promote indigenous knowledge. The conceptual analysis technique and literature review from research papers and scientific reports linked to STEM education were mainly used in this research work. The study established that indigenous knowledge plays a significant role in the provision of quality STEM education to African learners, and several ways of incorporating indigenous knowledge in STEM education were suggested. In addition, an integrated STEM model that promotes indigenous knowledge in the African context is proposed.

Keywords: *STEM education, Africa, Indigenous Knowledge, Inclusive Pedagogy, Education.*

8.1 Introduction and background to the problem

One of the key principles of the National Curriculum Statement Grades R-12 in South Africa clearly states the "valuing of indigenous knowledge systems" (DBE, 2014). The curriculum is therefore alive to the importance and crucial role that history and heritage of a people play in nurturing the values of a free and democratic country. In this regard, the education curricula that were presented to Africans on the content was modelled along Western epistemologies following the colonization of African states by European settlers (Kay & Nystrom, 1971). This certainly was not in the best interests of indigenous peoples since the curriculum was alien to Africans and it also perpetuated a sense of inferiority of African cultures and beliefs (Rodney, 1972). In summary, education systems on the African continent were

racially segregated where whites had access to high-quality education whereas Africans were exposed to an inferior education system that was systemically designed for their exploitation (Zvobgo, 1981). In his classic manifesto, *The pedagogy of the oppressed*, Paulo Freire (1971) posed the following question: "How can the oppressed, as divided, unauthentic beings, participate in developing the pedagogy of their liberation?" Perhaps the answers to this question may be the desirable pursuits in embracing indigenous knowledge and in turn "liberate" the general populace on the African continent.

It is generally appreciated that there is a strong correlation between economic prosperity of a nation and the provision of quality Science, Technology, Engineering and Mathematics (STEM) education (Mutsvangwa, 2021). Countries at the forefront of scientific and technological innovation have enviable and robust economies and their citizens lead comfortable and decent lives. Unfortunately, the same cannot be said of the vast majority of the African continent's populace. Africa as a continent is besieged with challenges that include incessant conflicts, famine and poor access to basic amenities such as clean water and electricity (Mutsvangwa, 2021). In addition, Africa lags behind in the provision of quality basic STEM education. Literature is replete with numerous comparative indicators that demonstrate how the African continent trails other parts of the world in terms of STEM education and its attendant advantages (Khumbah, 2018; Formunyam, 2020). These challenges are widespread and include lack of sufficiently qualified teaching personnel, poor infrastructure, inadequate funding, and curricula that fail to

respond adequately to the needs of the learners (Maila & Ross, 2018; Mkandawire et al., 2018).

8.1.1 Research Questions

To address some of the challenges stated in the preceding section, this paper strives to answer the following key questions:

- What is the role of indigenous knowledge in STEM education from an African perspective?
- How can indigenous knowledge be incorporated into STEM education in African curricula?
- What model may be proposed to promote indigenous knowledge in STEM education in Africa?

8.2 Theoretical Framework

This study is premised on the theoretical framework of inclusive pedagogy. Inclusive pedagogy in an approach that aims at enabling all learners sufficient access and a welcoming environment in an educational setting (Florian & Black-Hawkins, 2011; Sanger, 2020). To accommodate all learners, crucial adaptations of the "normal" curriculum need to be implemented accordingly. These adaptations should in no way be misconstrued to imply lowering the bar in terms of rigour and depth of the curriculum, but instead, should result in a more inclusive and positive learning experience that is cognisant of the learners' cultural ethos and beliefs. It therefore implies that inclusive pedagogy promotes an equitable approach to relevant educational resources and thus instils a sense of belonging and social justice among the learners. Different scholars use the term

inclusive pedagogy in varied contexts such as racial, cultural, socio-economic status and special educational needs (Kamenopoulou, 2018; Sanger, 2020). In this study, an inclusive pedagogy approach as articulated by Kirkness and Barnhardt (1991, 2001) is adapted. The approach places the educational needs of indigenous learners at the centre so as to tap into the optimal potential of these learners through the incorporation of their cultural practices into the curriculum. Kirkness and Barnhardt (2001) propose the "four components" (four R's), for an inclusive pedagogy, and these are: Respect, Relevance, Reciprocity and Responsibility.

Respect: this component emphasizes that there are numerous ways of acquiring knowledge, and indigenous knowledge systems should be embraced and afforded the place that they duly deserve in the curricula. Typical examples of respect may include the use of indigenous cultural norms and practices in the curricula across educational systems (Ragoonaden & Mueller, 2017).

Relevance: this facet of an inclusive pedagogy affirms the diverse cultural backgrounds of learners in any educational system. The curricula should be culturally relevant and acknowledge the role indigenous knowledge plays in the acquisition of knowledge. This calls for the infusion of cultural ways of knowledge generation with the more modern and "accepted" ways of formal settings (Reano, 2020).

Reciprocity: this construct privileges the point that educational settings should strive to promote mutual benefit to both the learners and the teachers. In so doing, this dispels the myth that learners are blank "tabula rasas", and the teachers are the only

knowledgeable ones who should transfer their knowledge to the "passive" learners.

Responsibility: this component highlights the importance of involving all cardinal stakeholders so as to achieve greater educational success for learners. These stakeholders include government departments, local businesses, community politicians and leaders, technocrats and indigenous community leaders.

8.3 Research Method

In this paper, academic journals, conference proceedings and books related to indigenous knowledge and STEM education were used to review and analyse the role indigenous knowledge plays in the provision of quality STEM education in the African context. Academic databases such as Education Research Complete and the Education Resources Information Center (ERIC) were consulted to obtain the relevant literature. Due to the nature of this work, the literature review method was applied to situate the study in an existing body of knowledge to selectively choose pertinent literature and to evaluate relevant trends linked to the topic at hand. Furthermore, literature from reputable sources was also sufficiently interrogated to identify gaps that were carefully analysed so as to produce a proposed model that crucially promotes indigenous knowledge in the offering of STEM education in Africa. In essence, purposeful selective inclusivity of the reviewed literature that is audience-appropriate and transparent was implemented to safeguard the integrity of this study.

8.4 Theoretical Perspective

8.4.1 The role of Indigenous Knowledge in STEM education

The term indigenous knowledge (IK) is generally defined as the local knowledge possessed by and unique to a specific culture or society (Warren et al., 1993; Wilson, 2008; Kim, 2018). Shizha (2008) maintains that, given the pivotal role IK plays in all facets of life for Africans, it would be a grave infraction and some form of "cognitive imperialism" if such knowledge is not incorporated in the curricula of African schools. Shizha (2008) further argues that IK should be incorporated into science education curricula so as to align it with the learner's lived experiences that are punctuated by their socio-cultural philosophies and practices. The issue of incorporating indigenous knowledge into basic science education curricula is an ongoing process that has been an erstwhile debate (Barnhardt & Kawagley, 2005; Msimanga & Shizha, 2014; de Beer, 2019; Jin, 2021). Banda and Banda (2018) posit that Africans use their everyday lived experiences and proverbs to generate and disseminate new knowledge that is free from exogenous cultures. The acquired knowledge has a lifelong impact on the learners since it is premised on familiar practices and beliefs. The scholars further argue that Western-based knowledge systems can be beneficial in Africa only if they are anchored in and expressed through indigenous knowledge practices and systems. From the aforesaid viewpoints, it may be inferred that indigenous knowledge solidly supports social constructivism in the sense that learners make meaning and acquire knowledge from their socio-cultural interactions with others. In their study, Bang and Medin (2010) noted that learners should be given the necessary support and motivation to traverse

the numerous epistemologies that they encounter within the science curricula. The scholars also claim that STEM education is not rarefied and should be carefully managed for the optimum benefit of the learners. Globally, several science textbooks often neglect the cultural component of science or simply limit it to a Western historical perspective (Forawi 2015; Khaddour et al. 2017; Ideland 2018; Zidny, 2020; Alexiades et al., 2021).

Snively and Williams (2016) define and explain the term Traditional Ecological Knowledge (TEK) as “the land-related, place-based knowledge of long-resident, usually oral indigenous peoples”, and as observed, regard it a subset of the broader grouping of indigenous knowledge and science. To bring into perspective the interconnection between indigenous knowledge, indigenous science and traditional ecological knowledge, Kim and Dionne (2014) propose the “cup of water” model presented in Figure 1, which depicts science “as a cup or container, and knowledge as the water that fills the cup” (Zidny, 2020). In this model, knowledge is viewed differently on the basis of the form of science that mirrors cultural traditions and norms of societies that relate to it. It is important to note that in this proposition, traditional ecological knowledge merely is a part of the entire indigenous knowledge possessed by a society and that it has some crucial relations and distinctions from Western science.

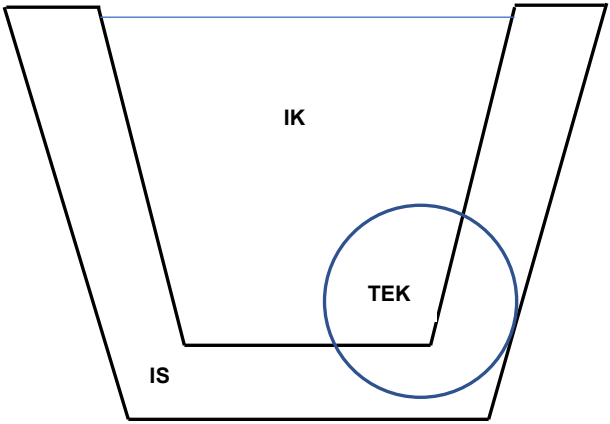

Figure 8-1: The relationship between indigenous knowledge (IK), indigenous science (IS), and traditional ecological knowledge

(TEK) (adapted from Kim & Dionne 2014)

A classic example of the extraordinary nature of the interplay between indigenous knowledge, indigenous science and traditional ecological knowledge is that of the Dogon ethnic group of Mali. Their impressive knowledge of astronomy was first verified by French researchers Marcel Griaule and Germain Dieterlen who were studying Dogon traditions and beliefs in the 1930s and 1940s. The Dogon tribe's most intriguing and prominent claim was that the star Sirius has a dark and invisible companion that has an orbit of fifty years (Griaule, 1970). They also claimed that the companion was very heavy and made of a rare metal that is not found on earth. This assertion was ground-breaking in the sense that Western scientists and astronomers were not aware of this companion of Sirius until several decades later when they

eventually discovered it through the use of sophisticated telescopes and advanced Physics theories and mathematical computations. This companion of Sirius was then named Sirius B.

From the preceding arguments and explanations, it is evident that several studies have been conducted that confirm the prominent role indigenous knowledge plays in the advancement of science education to indigenous populations in a given setting. It may further be argued that, by extension, the entire STEM cluster of subjects may enormously benefit African learners from the deliberate inclusion and incorporation of indigenous knowledge in the respective subjects and disciplines across the education curricula in African schools. This will certainly promote social justice in the schooling sector through the inclusion of all learners notwithstanding differences of their socio-cultural backgrounds.

8.4.2 Incorporation of Indigenous Knowledge into STEM Education

Having argued that indigenous knowledge plays an important role in the advancement of STEM education to African learners, ways should be sought that should make the incorporation of indigenous knowledge worthwhile to the African education systems. In their study, Alexiades et al. (2021) claim that, among other interventions, experiential learning that a student partakes in their indigenous community increases their knowledge and comprehension of the relevant subject matter. Yadav et al. (2011) are of the view that such initiatives increase learner engagement and arouse interest in analysing relevant data obtained from such types of experiential learning. Alexiades et al. (2021), Michell et al. (2008) and Snively and Williams (2016) further suggest that these

innovative ways of experiential learning establish direct links between learners, their communities and scientific knowledge, resulting in rich and deep learning that is relevant to the learners. This approach is certainly appropriate to more mature and advanced learners who would have acquired some basic understanding of the key tenets of their areas of study. Besides the development of formal programmes that infuse indigenous knowledge into STEM education, Bell et al. (2009) and Mack et al. (2012) propose that informal programmes that offer a great deal of flexibility and creativity should also be promoted to give learners a wholesome inclusive educational experience. The topics and themes that may be covered in such informal programmes include eco-philosophy, environmental education, and social justice. These themes are ideal for younger learners and should be taught as early as possible so that all learners establish the relevant connections and relationships between their environments, socio-cultural backgrounds, and STEM education. Adventure learning is another way of promoting the use of indigenous knowledge in the STEM disciplines. This is a learning approach that attempts to bring together real-life contexts and content through ways that enhance collaborations between learners, educators and "knowledge keepers" globally where they debate topical matters such as climate change (Doering, 2007; Miller et al., 2012).

8.4.3 STEM Education frameworks and models

Several STEM education models and frameworks have been proposed with the principal goal of promoting the provision of quality education to learners at different levels of study (Justi & Gilbert, 2002; Kelley & Knowles, 2016; de Vries, 2017; Hallström

& Schönborn, 2019). Some of the recent models include the proposal by Wei and Chen (2020) and Mutsvangwa (2021). Wei and Chen (2020) point out that there are four main characteristics that are essential for the provision of robust STEM education, and these are respectively, discipline knowledge, teaching strategies, expectations and learning systems. These scholars' model comprises a regular tetrahedron that has the above-mentioned characteristics at the vertices, and the entire tetrahedral shape is enveloped inside a sphere. The "context" component is also included in the model as depicted in Figure 8-2.

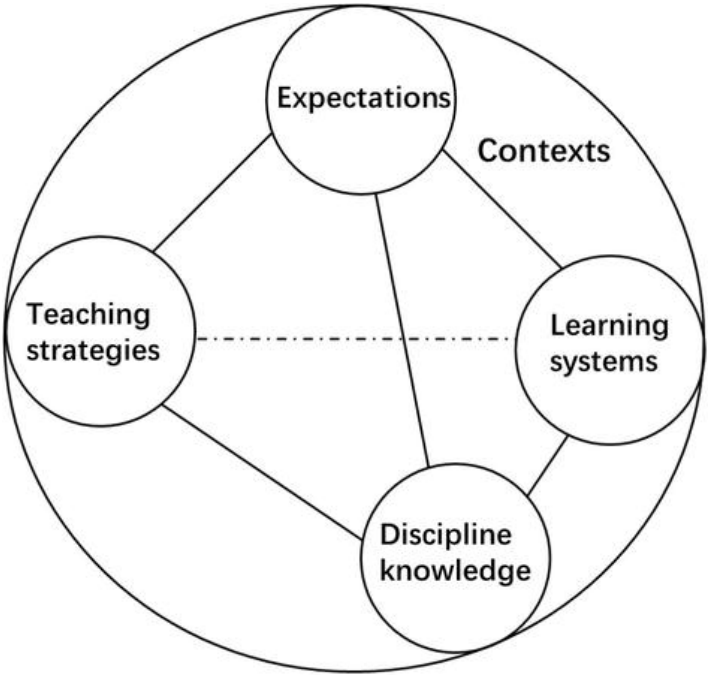

Figure 8-2: An integrated STEM education model (Wei & Chen, 2020)

Although Wei and Chen's (2020) model emphasises the importance of "context" in the teaching and learning of STEM subjects, it does not explicitly state the role of indigenous knowledge in pursuing an all-inclusive STEM education that is relevant to learners from diverse socio-cultural backgrounds. Mutsvangwa (2021) proposes a STEM education model that is particularly aimed at improving the quality of STEM education offering in a South African context. The model consists of four spheres of equal size forming a tetrahedral shape, and each sphere representing, respectively Science Education, Technology Education, Engineering Education and Mathematics Education

(Figure 8-3). The edges of the tetrahedron represent the “context” which is steeped in indigenous knowledge systems. This model places significant emphasis on the integration of STEM subjects and at the same time promotes the importance of context through indigenous knowledge systems, in contrast to the Wei and Chen (2020) model. Although this model captures and explains the most pertinent components in the provision and advancement of STEM education, its downside is that it privileges the importance of indigenous knowledge in STEM via an integrated approach of the STEM subjects. In essence, it marginalises the role indigenous knowledge plays within the constituent individual STEM subjects as it purports to limit its use solely in an integrated approach.

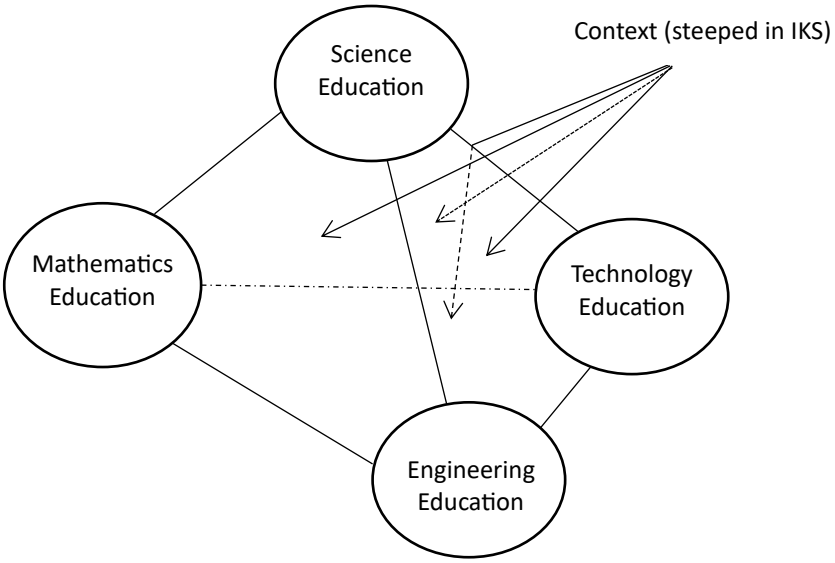

Figure 8-3: An integrated STEM education model that incorporates Indigenous Knowledge (Mutsvangwa, 2021)

8.4.4 Proposed STEM Education conceptual model that promotes Indigenous Knowledge

After reviewing and analysing some of the more recent models that promote the advancement of STEM education, I propose a new model that embraces some of the major components suggested in the available literature (Figure 4). The proposed model places significant emphasis on the pivotal role indigenous knowledge should play in the provision of quality and relevant STEM education in Africa. The model underscores the importance of inclusive pedagogy as an approach that, among other factors, ultimately promotes social justice in the STEM fields. In essence, the model is aimed at exposing all learners in the STEM subjects to quality education that is relevant to them and values their indigenous beliefs, and thus are able to relate to its content.

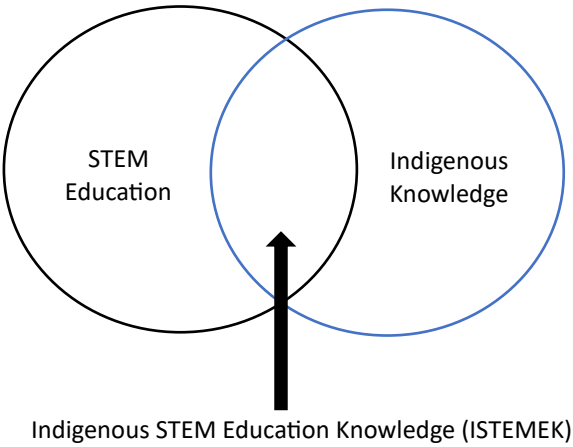

Figure 8-4: Proposed STEM education model that promotes Indigenous Knowledge

The proposed model has two circles that each represent STEM Education and Indigenous Knowledge respectively. The STEM Education circle is made up of both Western STEM content knowledge and African indigenous knowledge. On the other hand, the Indigenous Knowledge circle represents all the knowledge possessed by a particular cultural group, and this includes their beliefs about and knowledge of indigenous science, technology, engineering, and mathematics. The intersection of the two circles crystallises the most crucial component of this proposed model, the Indigenous STEM Education Knowledge (ISTEMEK). For the STEM education curricula on the African continent to be truly inclusive, relevant and meaningful to the learners, I am convinced that the curricula should sharply focus on ISTEMEK, and a large number of financial and human resources should be dedicated to the development of teaching and learning materials that promote this important component. As a result, the “four components” (four R’s) proposed by Kirkness and Barnhardt (2001) as crucial aspects for an effective inclusive pedagogy, will be incorporated into relevant African STEM education curricula. It is important to note that the proposal does not exclude Western STEM knowledge, but it brings to the fore the critical role that indigenous knowledge should play in the successful offering of the STEM curricula to African learners. Put in a nutshell, Western STEM knowledge and indigenous STEM knowledge complement each other in the broader curricula; thus, in the process realise the main goals of an inclusive pedagogy (Sanger, 2020). Another important issue is that the proposed model does not in any way diminish the integrity of each constituent STEM subject but makes the subjects appropriately authentic and worthy pursuing to the indigenous learners.

8.5 Discussion and Conclusion

The role of indigenous knowledge in the STEM subjects has been receiving attention, particularly over the last decade. However, most of the work that has been done to date has focused on other parts of the world such as Asia, Central and South America and Australia. Africa has been left out largely and it is imperative that this glaring gap should be filled. In this study, I reviewed and considered the role indigenous knowledge plays in the offering of quality STEM education in an African context. I also sought ways on how indigenous knowledge could be incorporated into STEM education, and lastly the study explored various STEM models that promote indigenous knowledge. It was established that indigenous knowledge plays a prominent role in the provision of quality STEM education to African learners, and several ways of incorporating indigenous knowledge in STEM education were suggested. Added to this, an integrated STEM model that promotes indigenous knowledge in the African context was proposed. The proposed model inherently incorporates the “four R’s” that are deemed essential for the effective adoption and implementation of a robust inclusive pedagogy.

In conclusion, this study reinforces the crucial role indigenous knowledge plays in the offering of relevant and quality STEM education in an African context. The proposed model is deeply anchored in the realisation of the importance of inclusive pedagogy in empowering African learners to succeed in studying the core STEM subjects so as to reap maximum benefit from their learning. Further studies in this area should explore other models that could firmly place indigenous knowledge at the heart of STEM

education for the ultimate benefit of African learners and the continent at large.

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Chapter 9

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