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African fractals as a tool for transformative education in Africa

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Abstract

Nature is replete with repetitive patterns in diminishing scales. Similarly, cultures produce recursive patterns that characterize their specific social, cultural, economic and political organisation. These self-similar, variously scaled and mostly infinitive patterns are called fractals. The uniqueness of African fractals emanates from the culture of the African peoples. Particular elements of these fractals have contributed immensely in mathematical learning especially in modern computing. This paper contends that the inclusion of African fractal education in curricula at all levels in Africa have the potential to contribute to better understanding of African identity, and promote African centred education that forestalls the alienation of the African from their environment. The paper argues that the teaching of African fractals in Africa is a needed project to facilitate understanding of the intricacies between nature and humans. It should deepen understanding about the concept of embedded humanity expressed in ideas of Ubuntu; and help awaken African consciousness about possibilities beyond empiricism. Recommendations are made on ways to include African fractals in the syllabus in Africa using the Ghana's pre-tertiary level (Senior High School) as an example.

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Résumé

La nature regorge de structures répétitives avec d'échelles dégressives. De même, les cultures produisent des structures récursives qui caractérisent leur organisation sociale, culturelle, économique et politique particulières. Ces structures auto-similaires, ayant d'échelles différentes et généralement infinies sont appelées les fractales. L'unicité des fractales africaines provient de la culture des peuples africains. Certains éléments particuliers de ces fractales ont énormément contribué à l'apprentissage des mathématiques, notamment, de l'informatique moderne. Cet article soutient que l'inclusion de l'éducation fractale africaine dans les programmes scolaires à tous les niveaux en Afrique pourrait permettre une meilleure compréhension de l'identité africaine et la promotion d'une éducation centrée sur l'Afrique qui découragera l'aliénation de l'africain par rapport à son

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environnement. L'article affirme également que l'enseignement des fractales africaines en Afrique est un projet nécessaire pour faciliter la compréhension des complexités entre la nature et les humains. Il approfondira la compréhension du concept de la solidarité humaine exprimé dans les idées d'Ubuntu; et aidera à éveiller la conscience africaine sur les possibilités existant au-delà de l'empirisme. Des recommandations sont formulées quant aux moyens d'inclure les fractales africaines dans le programme d'enseignement en Afrique, en prenant l'exemple du niveau pré-tertiaire (lycée) du Ghana.

Mots-clés: fractales africaines, empirisme, Ubuntu, solidarité humaine, éducation transformatrice, Ghana.

Introduction

Nature is noticeably irregular and replete with repetitive patterns in diminishing scales. In a word, it is fractal-like. A fractal comprises parts similar to the whole with subsequent shapes showing smaller sets of the original shape. It is conceived as a fragmented or rough geometric shape with each part of a fractal an approximated reduced-size version of the whole, recurring at multiple scales (Mandelbrot, 1987; Feder, 2013; Sala 2006). The diminishing scale, however, makes it possible to view fractals alternatively as increasing from the smallest shape to the largest and simultaneously as smallest to largest and largest to smallest within and up unto infiniti.

Similar to patterns in nature, cultures also produce recursive patterns that characterize their specific social, cultural, economic and political organisation. Generally, complex networks from sociology, biology to technology share fractal principles of organization (Song et al, 2016). Social, metabolic and cellular networks therefore demonstrate network dynamics depicting multiplicative growth and scaling in a self-similar way.

In the context of many parts of Africa, the principles that guide the characterization of fractals in nature and their mathematical creations have been applied in trades, architecture, social organization and games among others. Against this prevalence of the application of fractal principles, features and designs in Africa follow observable patterns in nature. The artistic and architectural patterns of African cultures demonstrated patterns relating to self-iterative or recursive computation. The symbolisms and designs across the continent also show remarkable iterations and self-similarities. Additionally, social settings be they spirituality or interpersonal and group relationships, and village housing, show recursion close to those of nature. It is in this context that Eglash (1999) describes the fractal principles as applied in Africa as African fractals. African fractals emanates from the artificial realm of culture and does not imitate nature while applying fractal principles. Expectedly the shapes consciously and sometimes otherwise created do not conform to the conventional shapes that are usually studied in the mathematical world.

A close study of the African way of life therefore reveals that African fractals, as a core aspect of the indigenous knowledge system in Africa, furthers

understanding about African social life and relations with the environment and nature in general. Before Benoit Mandelbrot coined the term fractal and revolutionized this geometry rejected by mainstream mathematics and physics, fractal principles were observable in African textile designs, board games, hair style, town planning, architecture, kinship patterns and belief systems in the various complexities and linkages it presents between human, nature and the spiritual world (Campbell, 2010b; Agozino, 2007).

Thus African fractals could be understood as mathematical thinking expressed in arts and organizational forms. Fractal geometry explored from the realms of culture therefore furnishes understanding about the underlying structures of African society in relation to the world of mathematics and science. The figures below presents examples of application of fractal principles in the Adinkra symbolism in Ghana.

Fig. 1: Adinkrahene
(Symbolizing royalty)

Fig. 2: Nea onnim no sua ohu
(Knowledge through learning)

The term African fractals should not be misunderstood however to mean that all fractals across Africa are the same or have the same political, social, economic or cultural interpretation. Nonetheless, it is critical to understand it as the prevalence of a technology across a heterogeneous society, albeit with shared experiences such as enslavement, colonialism and imperialism. Put differently, the diversities in Africa notwithstanding, the particular technical principles at work (fractal principles) apply in the differing parts of the continent where fractals as outcome of cultural undertakings could be observed.

The significance of African fractals notwithstanding, the principles and knowledge about fractals have yet to appear in the education syllabus especially in the pre-tertiary levels in most part if not all of Africa. It is therefore essential to include fractal knowledge in the education of the current and future generalizations within the formal education system.

Focusing on African fractals as one aspect of the rich knowledge systems in Africa, this paper contends that the inclusion of African fractal education in the curricula at all levels in Africa have the potential to contribute to better understanding of African identity, and promote African centred education that forestalls the alienation of the African from their environment.

Not least because fractals are embedded and continuously reinvented in the African way of life connections with the environment. The teaching of African fractals in Africa is thus a needed project to facilitate understanding of the intricacies between nature and humans. It should deepen understanding about the concept of embedded humanity expressed in the philosophy of Ubuntu as well as progressive thinking in the way Africa plans about transforming the continent within few decades. These tasks of teaching and deepening understanding about fractal knowledge as indigenous knowledge systems is necessary to the transformation of consciousness which is central to transformative education in Africa.

This everyday mathematics, practiced by the Africans who are engaged in basketry, fencing with weeds, braiding and games like 'oware' should therefore be central to academic discussions at elementary, high school, college and university levels in Africa. Alternatively stated, African fractals should be central to knowledge production and dissemination at all levels of education across the continent. This form of knowledge production should contribute to renovating African culture and inspiring confidence among Africans in order to accelerate economic, psychological and social transformation in Africa. The paper will attempt to show how fractals can be included in course content using the example of Ghana's high school mathematics syllabus.

The subsequent section examines how African fractals[5] contributes or could contribute to transforming education for the transformation of Africa. This will be followed respectively with investigation on fractal geometry, principles and application; fractals and environmental conservation, fractal wisdom, fractal optimism and transformative education; a tinkering with Ghana High School Core Mathematics Syllabus and conclude with emphasis on harnessing this indigenous knowledge systems for scientific, social, political and economic transformation in Africa.

African fractals and transformative education in Africa: A review

Education is understood as the transfer of knowledge between individuals, or generations (Adu-Gyamfi et al. 2016), and among individual(s) and group(s). The knowledge transmitted may comprise customs, values, ideas, observed natural patterns, philosophies, experiences and skills shared in a more formalized setting or via informal social interactions. In this exercise the transmitter enforces personal or received norms into which the participants are initiated. In the more formalized structures, information control is paramount as the syllabus influences knowledge contents in academic and other educational sectors. Particularly, the syllabus shapes the discourse in the

[5] African fractals and fractals will be used interchangeably in the paper. This works well when we view African fractals as cultural appropriation of fractal principles occurring in nature and geometry.

formal structures of education and the setters of the syllabus and examination questions control the kind of education that is received (Brocke-Utne, 2008; Frehiwot, 2015). This control may provide for the personal or collective self-perpetuation of the determining person or group(s). Thus as Frehiwot (2015: 297) succinctly contends, are the primary avenue for developing and disseminating social standards, policies and political agenda, education may serve the purposes of "humanization and/or dehumanization" of the educated and their societies. Frehiwot could add that the purposes thus served could be reproduced by the educated in advancing the goals of the educator, the collaborator or both.[6]

Within the context of information control, the socialized individual however has an agency in accepting, modifying or rejecting the knowledge transferred based on observed realities and/or available counter information. It is within this understanding that the activism of foreign trained Africans prior to decolonization and after may be appreciated.[7]

Africa had been the first continent to be literate and have a school system (Ki-Zerbo, 1990). The teaching systems of Egypt and the first degree issuing university of Morocco combine with the universities of the Northern Sahel including Timbuktu to remind us of the growing rich intellectual traditions that would be truncated in the periods of colonial invasions.[8] In most parts of Africa, however, the formal education system introduced in the colonial period have been the mainstay of school-based knowledge transmission. This form of education has been criticised for its continued subservience to the needs and dictates of the erstwhile colonial forces. This formal system of classroom education is construed as alien to African society in that it is not rooted in the African environment. In its mainstream, it has produced forms of knowledge that promote division between humanity and nature, supremacist ideas, and engenders destructive forces that threaten the existence of planet earth. Within this understanding, there is an increasing call for the production of knowledge and understanding that will rehumanize the planet and dismantle hegemonic structures that hinders same form of knowledge. It is this process of knowledge production and dissemination that has been described as transformative education.[9]

In its attempt to produce and disseminate knowledge, transformative education seeks to revive knowledge systems that (should) contest and override forms of misinformation that projected indigenous knowledge as primitive and unimportant. It exposes how knowledge may have been

[6] Educator and educated respectively refer to the transmitter of knowledge and the recipient of such knowledge. The collaborator is the educated (student, pupil etc) reproducing the knowledge received.

[7] Joseph Ki-Zerbo for instance was trained in France but became activist scholar in promoting indigenous approach to education and transformation (Badini, 1999).

[8] Ki-Zerbo (1990) and the Guinness World Records have well documented these facts.

[9] See for example King (2005).

appropriated sometime in history to advance the interest of the controllers of information. This attempt to misinform and suppress history may be best classified as information warfare. It is in this contestation that educational content is critiqued and the infusion of neglected yet important education promoted so that there may be liberated thinking about organising African society. The transformative task may thus encompass the re-education of the educated and the reinterpretation of the understood as well as the establishment of environmentally friendly education for Africa (Okpalike, 2014). In this process of re-education and reinterpretation, African knowledge systems are central parts to knowledge production and teaching in Africa for social change. Nabudere (2006: 7) reiterates the need for a knowledge production for social change when he contends that:

> African scholars must pursue knowledge production that can renovate African culture, defend the African people's dignity and civilizational achievements and contribute afresh to a new global agenda that can push us out of the crisis of modernity as promoted by the European Enlightenment. Such knowledge must be relevant to the current needs of the masses, which they can use to bring about a social transformation out of their present plight.

In calling for fresh perspectives and understanding about global crisis and solutions, Nabudere may have sought to inform us about the neglect of mathematics rooted in the cultures of the peoples of Africa. It is Shirley (2001: 85) who more boldly shows how throughout the period of formal education facilitated by Europe, mathematics in other cultures were given no attention or treated as periphery if it was ever to be considered. In that work it is observed that,

> The idea of looking at mathematics in other cultures and using these findings in an ordinary classroom may have seemed strange to most teachers and, at best, considered as a possible topic for enrichment. In many parts of the world, mathematics instruction was based entirely upon a European model of content, structure, and algorithms. School curricula as well as instructional practice had gone through reforms such as the "New Math" programs of the 1960s, but remained largely centered upon European (and later, American) patterns that had been established decades earlier.

This being the case, it is needful to revisit the mathematics present in cultures for the purposes of transformative education to be achieved. The integration of African fractals into the education curriculum is a key step in this task. Such integration could provide Africa and the rest of the world with the rich knowledge and intellectuality in the "African indigenousness and way of being

and doing" and the hope this mathematical approach stirs for the exploration of opportunities beyond what is empirically justifiable. It could in the long run contribute enormously towards the mitigation of some of the problems of humanity such as uncontrolled desiccation of water bodies (Brock-Utne, 2008). Such education is thus central to accelerating planning to repair and replenish the planet earth. The understanding of the statistical and spiritual relationship between humanity and nature proscribes and seeks to minimize actions that distort the link among humans, the natural and spiritual world. In most parts of Africa, the earth and water bodies are treated as spiritual entities which are to be offered corresponding respect in how humans relate with these and related entities such as trees.

The challenge to incorporate African fractals is part of the processes to re-educate and democratize the content of education in Africa. This undertaking is necessary to freeing the African mind considerably restrained by forms of Eurocentric education which does not allow much space for deep thinking into Africa in an emancipatory manner to grasp the possibilities that abound within the continent for its transformation.

Education in African fractals however goes beyond mathematics relating to geometry, geometric progression and scaling. It reveals the mathematics in the very lives of the African peoples as reflected diversely in their differing cultures across the continent (Eglash, 2009). It presents and seeks to strengthen the basis of thinking that goes beyond the present reality. African fractal education would train the student not to ignore the existence of the objective facts. However it would teach the student that there is more to be known than what the facts have shown. At the very least, the study of African fractals in all its ramifications would be a reflection of the recognition of democracy in academia; that there is plural availability of knowledges and not only the universal validity of a particular science rooted in and limited to the experiences and cultures of one group of people (Visvanathan, 2009).

Given the general forms of education that exist across the world and its seemingly restrictive nature, increased addition of indigenous systems and forms of learning into academic discourses may in the final analysis benefit all humanity by providing alternatives ways for understanding prevailing global challenges and proffering possible solution(s). Brocke-Utne (2008) for instance, identifies the benefits of integrating indigenous knowledge systems with the rest of the world. This argument has been reframed by Masemula (2013: 60) that the

> integration of indigenous knowledge systems into the curriculum should ideally not be confined to Africa but shared with the rest of the world in order to offer the world values contained in the African indigenousness and way of being and doing which could help in

meeting the challenges facing humanity outside Africa

This quest to make available indigenous knowledge to the rest of the world, from an African point of view, is central to the Nkrumist assertion that the emancipation of the African is the emancipation of humanity everywhere. It is thus important to emancipate the African mind from forms of informational hegemony that tends to subjugate the African and deprive humanity of alternative ways of knowing and solving our problems and celebrating our successes.

The teaching of African fractals is one of the key ways to raise African consciousness and rekindle the African mind and deliver it from various forms of misinformation and miseducation that had served as key weapons to break the will and self-reliance of the African. The inevitability and centrality of disinformation and miseducation in achieving the colonial aim of domination is clearer when the impact of these efforts are viewed with respect to the replacement of almost everything African which in turn has worked considerably well to facilitate the loss of self-esteem among many Africans. It is the continuing semblance of education in Africa to those of the colonial times that has affirmed assertions that such forms of education ensures that western understanding and interpretation of Africa and African life is maintained through a network of elite who could promote "Western interests within a seemingly African struggle" (Okpalike, 2014: 178).

Consequently, this form of education seems to entrench and advance thinking about a helpless African situation, a gloomy continent, and attempts to discourage the African about possibilities for self-engineered efforts towards transformation and better quality of life. Fractal education is therefore one of the attempts to restore the self-esteem of the African people. It is central to the form of re-education essential to reminding the African about their prevailing capabilities and diverse contributions to ancient civilization (Blyden, 1974).

Given that formal education has become one of the core modes of dissemination of knowledge, values and capabilities, it is necessary to include this form of mathematics, that is more familiar to the African, as well as the social and political leanings of such mathematics into the curricula of these formal structures. This effort may serve to rekindle the African mind and the many African peoples who engage in forms of trade and exercise that employ fractal principles to embrace mathematics in its varying forms. Thus these may contribute to exploring the scientific and mathematics aspects of the African knowledge systems for accelerated transformation of the continent.

The next section will examine fractal geometry, fractal principles and some of the ways these principles have been applied within Africa and outside the continent.

Fractal Geometry

Geometry is mostly understood to mean the mathematics of points, lines, shapes, curves and surfaces. Following this explanation, fractal geometry could be understood as the mathematics of shapes that do not conform to conventional shapes of circles, rectangles, cylinders, and prism to name a few.

Ever since Euclidean geometry became known, there has been contentment with the idea of classifying all objects as compositions of regular geometric shapes (Sela, 2006). Consequently, circles, rectangles, and triangles among other regular shapes have been the core of mathematical construct. This form of geometry has been found to shape the architecture of most of Western Europe where Euclidean geometry manifests in the outlooks of many parts of the built environment.

It was after Mandelbrot's (1983) work that fractals came to the fore in discussions about geometric shapes that do not conform to closed spaces. This development may have also provided the impetus for furthered considerations about the possibilities that in analysing closed spaces there could be circles of circles within a circle, and rectangles of rectangles within a rectangle, miniature circles or rectangles been self-similar with the whole.

Just as Euclidean geometry may have influenced the structure in the built environments in the West, fractals had served as an important technology for the construction of buildings and settlement forms in parts of Africa. In the case of Africa, however, many villages were built over many generations with no one in charge of ensuring a particular order of the scructures and yet they show a consistent fractal pattern for the village as a whole (Eglash, 1999). The influence of Euclidean shapes and fractal geometry on settlements in USA and Africa, for instance, is explained by Eglash and Odumosu as an example of mathematics as practice, that is, "systematic material and symbolic understanding of quantity and logic" (Eglash and Odumosu, 2005: 101).

Sala has provided much insight into the general importance of fractal geometry including the potential for defining new architectural models. The main contention in this light has been that,

> Fractal geometry can be used in the process of supporting creativity in the ideation of new forms and for testing harmony between old and new. It is helping to define new architectural models and an aesthetic that has always lain beneath the changing artistic ideas of different periods, schools and cultures (Sala, 2006: 172)

In the current age of three dimensional (3D) designs using computing techniques, it is not difficult to follow the above argument regarding the creation of new models which follow principles used in developing artistic

works over several years.

Fractals Principles

The analysis of fractals has been premised on the observation of the application of five main components of fractal geometry, viz, recursion, scaling, self-similarity, infiniti, and fractal dimension. In this paper two additional features would be discussed, namely complexities and interconnectivity. These two features will later help to further understand the social and political implications of fractal geometry in Africa.

Recursion

Fractals are created through an iterative process involving a loop mechanism whereby the output of one stage serves as the input to the following stage. For the continuation of the operation to be possible, the results are returned in a repeated manner within a set range of scales or continues to infiniti.

Self-similarity

Each portion of the pattern resembles a reduced scale of the pattern or an increased scale of the same (Lam, 2009). The distinction here is that there is statistical self-similarity and not exact self-similarity (Eglash, 1999). Put differently, self-similarity does not imply that the subsequent shape, the reduced or increased scale of the pattern, is exactly the same as the whole or the previous scale. The shapes within the whole pattern however show semblance across the pattern in recognizable ways.

Scaling

A fractal shows patterns for a particular range of scales. Similar patterns can therefore be observed at differing scales within the selected range (Eglash, 1999). In the natural setting, it is could be observed that branches of the fern, for instance, like many other branches of trees, show a consistent decrease in size towards the tip of the branch. The reverse trend also holds true for understanding scaling. Thus the scale diminishes towards the tip and increases towards point where the branch connects to the main tree.

Fractal dimension

In what is understood as topological dimensions in classical or Euclidean geometry, a point has a dimension value of zero; a line, an area and a volume have one, two, and three dimensions respectively (Lam, 2009). The Euclidean dimensions are thus expressed as integer values. Fractal geometry, however, shows arithmetic progressions that do not conform to the dimensions of classical geometry. Alternatively stated, the statistical progression at work in developing fractals do not fall into zero, one dimensional, two dimensional or

three dimensional figures. They mostly occur within these dimensions. This means that the fractal dimension for a point pattern will be a non-integer value that could fall anywhere within zero and one. Fractal dimension of a curve can have non-integer value between one and two, and that of a surface within two and three contingent on how complex the pattern may be (Lam, 2009). It could therefore be inferred that fractal dimension exceeds the topological dimension in thinking about dimensions of points, lines, curves, and surfaces among others. In fact this has been how Mandelbrot had defined fractals as the set where the fractal dimension strictly exceeds the topological dimension (Mandelbrot, 1983).

Infinity

The patterns making up a fractal could continue in the reducing scale endlessly, that is, up to infiniti. It does not mean however that fractals cannot be limited to a finite range of scales and sets. Indeed physical objects remain fractals within defined set of scales (Eglash, 1999). Nonetheless the dimensions that could be mathematically generated in the creation of fractals show that a never ending pattern can be developed in the formation of fractals.[10] In this case, the patterns within set range of scales could be understood as part of the elements in infiniti.

Complexities

Fractal patterns are complex. They are nearly impossibly represented by simple lines and curves (Sala, 2006). Where simple lines or curves are applied in attempt to depict fractals, they soon becomes complex after some iterations. The forms that are indicated or shown in fractal designs may not necessarily lean themselves to known artificial shapes that show regular forms in their construction. The intricacies that exist among parts cannot be neatly teased out in the natural, social and spiritual ramifications of the geometric principles. It models some form of chaos.

Interconnectivity

The possibilities of shapes within shapes of differing scales and sometimes many linkages with other parts of the whole signifies how interconnections exist in fractal patterns across design forms.

From observation in nature to the conscious artificial creations, the shapes and elements that form a fractal phenomenon usually connect to a parent node and with each other and one another across the reducing scales.

[10] See Fractal Pack 1 Educated Guide. Available at www.fractalfoundation.org

Some application of fractals

In the initial stages of the embrace of fractal geometry, this mathematics was applied to the study of natural phenomenon from trees, mountains to clouds (Eglash and Odumosu, 2005). Along this path, Masi and Maranville (1998), for instance have applied fractals in the analysis of sorghum root system morphology using fractal dimensions to distinguish branching patterns of sorghums of African origin, US origin and hybrids of the two.

Subsequent years have however witnessed the application of fractals not only in computing but also biology, soil science, medicine, finance, geography, geology, entertainment (film), physics and space science. Lam (1990) for instance has applied fractals in describing and measuring Landsat images and Scholz and Mandelbrot (1989) indicate fractals in geophysics.[11]

In many communities in Africa, fractal geometry continues largely to be applied in basketry, hairstyling, board games, arts and social relations. Beyond the continued importance of these forms of applying fractal principles in Africa, however, the challenge for the present generation includes the application of what has been prevalent in the communities, villages, towns, art shops, saloons and spirituality in the teaching of mathematics. Also crucial is the understanding of the importance of fractal principles in discussions about peaceful co-existence, environmental conservation, grassroots mobilizations and continental organization as well as rethinking around how Africa could be transformed. This endeavour would mean mathematics in African classrooms become situated in the cultural setting of Africa. Thus the intersection and interrelationships among mathematics, science and the social may be better appreciated. This view resonates in Gerdes (1998) where he forcefully contended that situating mathematics in the cultural context of the student could provide better foundation for understanding mathematics and science.[12] Thus by emphasizing the mathematics in African culture, African students may better appreciate other aspects of indigenous knowledge systems for the transformation of the continent.

African fractals, interconnectivities and environmental conservation

A key character of fractals is the principle of complexity and interconnectivity among the various elements of differing shapes and sizes that constitute the fractal structure. This complexity and interconnectivity could be observed in the form of living relationships and organizations that has informed African existence (Eglash and Odumosu, 2005). In other words, the African way of thinking, organising and living depicts an understanding that reflects the principles of interconnectivity that is central to fractals. It

[11] Mandelbrot (1997) shows fractals in finance; Barton and La Pointe (1995) is an edited volume on fractals in petroleum geology; Mandelbrot (1984) analyses fractals in Physics. The list could continue.

[12] See also Gerdes (1998b, 1999, 2011). Frehiwot (2015) partly furthers this view in positing that education, as cultural instrument, should directly reflect the backgrounds and aspirations of the educated.

is this understanding among people in the community that is expressed as Ubuntu. The Ubuntu way of living in peaceful coexistence and sharing could be understood as expressing an idea of embedded humanity. That is the humanity of one person is expressed through the humanity of another. This interconnectivity extends beyond two lives into a simultaneous mathematical mapping that could be understood as one to many and many to one. Within this understanding the individual exists because the other person exist and because the entire group exists. Stated alternatively, "I am because we are". The emphasis therefore is on togetherness, shared values, shared lives, and shared humanity.[13] The idea of Ubuntu is obtainable in most parts of Africa and has several forms of rendition. In Ghana for example, the principles of Ubuntu is expressed in part among the Akans, for instance as "baakoye" (which literally translates into oneness).

It is worth emphasizing that the African understanding of the principles of Ubuntu extends beyond the view of the African among themselves and shows the readiness of the African person to coexist with non-Africans and humanity for that matter and this willingness is continuously exhibited in the usually hospital attitudes and gestures that is prevalent in many parts of Africa.

The interconnectivity and complexities observed in African society does not end at the human level. In fact, the belief systems and spirituality as well as social arrangements in most of Africa shows remarkable application of fractals. In African spirituality, for example, humans belong to a complex whole that involves the ancestors, gods, and a supreme deity. In this connection, currently living humans are answerable to the ancestors who among other responsibilities entrust into the hands of the living family and community properties for utilization and safekeeping for the generations unborn. Humans also connect with the many differing gods who operate and oversee diverse parts of nature and the hierarchy extends to the Supreme Being who has the ultimate control and share of power in a complexity that has been admittedly and necessarily simplified in these few lines.

Equally important to the understanding of the operations of African fractals is the social arrangement and relations that exist among peoples in the community. It is in this area that we infer from the fractal structures in Africa the unique mapping of social scale on a geometric scale in relation to the construction of settlements as is the case of the Kotoko in Cameroun (Eglash, 1999). In this socio-geometric scaling, people in the various classes of society have their houses connected with one another up to the head of the family or village. The various houses, however, also connect to the central shrine which serves as the spiritual force binding the entire community or clan together.[14]

[13] This explanation resonates in Campbell (2010).

[14] For more discussions on the various fractal settlements see Eglash (1999).

A key component in examining the complexities and interconnectivity among Africans and the spiritual is the relations of humans with the environment. In the African ideation system humanity is connected with nature. This fractal principle of complex interconnectedness thus facilitates understanding of the intricacies between nature and humans. Africans severely have demonstrated intimate connection with nature including plants, rivers, animals, and inorganic materials. It is within this philosophy, teaching and practice that the significance of the deification of natural phenomenon across Africa is foregrounded in relation to environmental conservation. In this knowledge system, animals, the blue economy – all of the water bodies- the trees, and the earth are seen as (home to the) gods and goddesses. This conceptualization of nature provided a sense of respect for the earth, animals, trees and other resources across Africa. In the book *Mammy water in Igbo culture: the Ogbuide of Oguta Lake* Sabine Jell-Bahlsen has furthered understanding about the African perception of water bodies and reverence for the blue economy as the habitat of some deities commonly known as "Maame Water" - Mother of Water or Mother Water (Jell-Bahlsen, 2014). This book follows traditions which document the daily living experiences and religious explanations of African peoples from the point of view of Africans. It is within this tradition that African conceptions of relations with nature is appreciated in its function to provide a wedge against untrammelled domination of nature that had been witnessed in the many parts of the world and especially in Europe where industrialization and capitalist globalization largely meant destruction of the earth by humanity.[15]

The complex linkages between humans and nature is also reflected in the various symbolisms and prohibitions that guide clan and community living in Africa. One of these important symbolisms is the totem system. In many parts of Africa families and clans are associated with particular symbols, usually animals, that provide in part a guiding principle to the actions and orientations of the particular clan. There also exist fatherline animals that the individual connects to through their paternal lineage. Taken together, these animals are forbidden food to the members of the particular clan and individuals who have connections with them. This, in a great way, *ceteris paribus*, offers some mechanism to promote to a considerable extent a balance between human and animal population in Africa. The symbolism also extends to trees and vegetation viewed as providing habitation to deities and healing to the community.

[15] Nolan (2009) one of the key followers of the destructive effects of globalization has offered an analysis of the impact of these trends on the planet earth. He contends in part that "unconstrained, wild capitalism threatens fundamentally the very existence of the human species. The global ecology is profoundly threatened by the locked-in pattern of consumption, distribution and energy consumption that is at the heart of capitalist globalization" (41).

In the book, *Healing Wisdom of Africa,* Malidoma Patrice Some has emphasized the spiritual values that are key for healing in the world. This book clearly underscores the fact that in Africa, these healing values largely derive from the complex connections among Africans in a community and between the African person and the natural world (Some, 1999). The understanding of the fractal interconnectivities and complexities between humanity and the environment is therefore essential to the preservation of nature and harmonic existence between humans and their ecology. In the view of this paper, this fractal interpretation of human-nature relationship is central to attempts to repair and rehumanize the planet earth.[16]

Given the glaring effects of the previous periods of industrialization, and against the backdrop of the interconnectivities between humans and nature, Africa is challenged to innovate more appropriate ways to satisfy human needs, and undertake transformative projects such as industrialisation with environmental conservation in mind. More specifically, Africa's industrialization in the era of huge technological advancement and possibilities must embrace the bio-economy consciously moving away from the fossil economy (Campbell, 2017a).

Teaching and information about the human-nature relations is equally important to the success of African projects such the Great Green Wall of plants from Senegal to Djibouti to prevent the increasing spread of the Sahara to the South. The understanding of connectivity with the environment may thus facilitate the commitment of Africans to these reforestation projects. In the current context, where there is increasing pollution of water bodies in Africa through illegal mining activities and chemical waste from plantations, to give two examples, it is imperative to remind the African and humanity in general about the need to maintain the complex balance between man and nature. It is these times when it is even more important to emphasize to humanity and the African in particular the need to harness the mathematical relationship between humans and nature and the spiritual forces to protect the planet.

It will be crucial to reform the forms of education that removes the African from his environment and realities and incorporate these fractal understandings about the relations among humans and nature. From the foregoing discussion, it could be understood how the philosophy and teaching in Africa on Ubuntu in its fractal ramifications has weapons and strengths in the African environment and the living conditions of African peoples. Such knowledge provides an essential force for possibilities at peaceful coexistence, environmental conservation and environmental repairs beyond what is empirically tenable.

[16] Campbell (2017b) provides additional analysis of this interconnections and the importance of the kind of education that is vital for environmental repairs.

Fractal wisdom, fractal optimism and transformative education

In considerations of the significance of fractals as a central knowledge system, it is essential to highlight the organizational aspects and further explore the concept of infiniti in the context of planning for transformation in Africa. The fractal property of infiniti which explains how fractal shapes could be replicated endlessly, recursively and diminishingly in a fractal system, speaks in part to possibilities beyond current objective observations and achievements.

In attempting to secure some of these unknown possibilities for transformation, certain principles derivable from fractals could guide the forms of organising and planning towards realising desirable ends. The recursive feature of fractals in the diminishing scale applied on the shapes offers some wisdom which provides useful guidance to effective political and social organization. This mode of organising has been obvious in the mobilizations across Africa to end colonial rule and apartheid. The mobilization of youths and means of engaging the colonial forces that had been employed in gaining independence in one part of Africa were replicated in other parts, albeit within sometime varying details along the lines of the fractal principle of self-similarity. This way of organising is described as fractal wisdom.

Fractal wisdom emphasizes that effective social mobilization should start from the people, that is, the grassroots. That more importantly, for a wider mobilization of social forces to be more feasible this form of organisation should be reproduced across groups of differing sizes such that a recursive loop is formed through a network of self-organizing peoples at various levels in the pursuit of a social course (cf. Campbell, 2010a).[17] Kwame Nkrumah understood this principle well and promoted the self-mobilization and education of the Ghanaian youths to obtain independence for Ghana. Arguably, the whole process that would end colonial rule had been birthed through self-organizing groups including students, traders, and the intelligentsia across the continent of Africa (Frehiwot, 2015).

What fractal wisdom projects in times of urgent need to transform Africa in part, is that, there is need for grassroots forces including students, traders, miners, trade unions, professionals, and the intelligentsia to organize in interconnected networks to add impetus to the demands for a more formidable integration and transformation of African economies which would then secure better quality of life for the peoples of Africa.

The thinking about possibilities of transformation in Africa, however, need not separate from the idea of infiniti which is a core feature of fractals. This idea of infinity that characterize fractals teaches that there is greater opportunity than what has been known. It highlights that need to go beyond

[17] This paper outlined how the Barack Obama campaign had employed fractal wisdom in organising to win elections in the USA.

the objective fact and what is empirically viable to embrace the possibility which could be perceivable through a determined spirit and will (Campbell, 2017a). This implies that while conscious of the empirical evidences it is essential to strive to overcome the eminent hurdles. Stated differently, the principle of infiniti teaches the need to retain hope, focus and continuously work on the more possibilities that exist to be explored about a situation. This hope is encapsulated in what is called fractal optimism.

When Cantor created his sets, one of the understandings that was advanced was the possibility to create elements of a set within infiniti and track the set with its elements (Eglash 1999). By implication, within the endless limit of possibilities an individual, organization or continent can create and track its transformation to the extent that its will, energies and determination allow.

In 1963, there was an opportunity for Africa to lay the foundation for a more transformed continent.[18] This chance would however be blown away for a more gradual approach through regional groupings-Regional Economic Blocs. After a jubilee, the Heads of State of Africa solemnly declared their support and readiness for a continent-wide transformation. This transformation which is hoped to be seen within the next jubilee (2013-2063) encompasses grandiose projects such as the Great Green Wall, Highways crisscrossing the capitals of Africa, improvement in living standards of African people and ultimately a union government. This 50years plan to transform Africa is called "Agenda 2063: the African We want" (African Union Commission, 2015). Under the Programme for Infrastructural Development of Africa (PIDA), one of the frameworks for the implementation of this Agenda, few African heads have undertaking Presidential initiatives to facilitate the achievement of infrastructural targets of the continent (NEPAD, 2016).[19] The ambivalence of many African leaders, however. shows that there is the need for new forms of organisation spurred by fractal wisdom and fractal optimism.

In an era where many Africans have bought into the so-called empirical, objective facts and regressions and interpretation of Africa's numerous problems from chronic diseases, curse accompanying resource abundance, corruption, lack of political will for integration, to water scarcity as almost unsurmountable obstacles to continental transformation, there is the need for re-education about the untapped opportunities that exist and the possibilities beyond what has been known or perceived in order to facilitate the mobilization of energies for the transformation of Africa.[20]

[18] Kwame Nkrumah (1963) in *Africa Must Unite* documents some of the discussions that could have served as the basis for thinking about transforming the continent in an accelerated manner.

[19] NEPAD is short form for New Partnership for Africa's Development. NEPAD's 2016 Report shows the various Presidential Infrastructure Champion Initiatives and their respective progress.

[20] The thesis on Africa's problems are vast and varied. For discussions on resource curse see for instance (Sachs and Warner 1995, 2001).

It will be important, from the point of view of this paper, to emphasize the significance of fractal wisdom and fractal optimism to especially young minds but also all Africans in efforts across the various levels of the academy, in the streets, markets, workplaces and politics to override the forms of misinformation about the possibilities to transform Africa.

The question that requires further attention, however is how fractals, and African fractals in particular can be integrated into the syllabus across the academy and how to teach this knowledge system in the school system in Africa. It is in the attempt to proffer a possible response to this question that we examine in the next section how the teaching of African fractals can be applied in Ghana's educational system at the pre-tertiary level. Hopefully, the Ghana case will be an example for replication and iterations for Africa.

African fractals in Ghana's High School Education Syllabus

Ghana is one of the core centres for discussions on the transformation of Africa. The school-system in the initial had been modelled after the colonial system. Attempts have been made to reorganize the structure of the system over time (Adu-Gyamfi et al., 2016); however, apart from the study of select Ghanaian languages and culture, the content shows a very limited inclusion of knowledge about traditional ways of knowing and no mention of African fractals, fractal geometry or fractals and its significance in understanding relationships and mathematics in Africa.

Thus in recommending the inclusion of fractals in the education system for transformation on the continent, the country provides a fair avenue to explore how this African mathematics could be taught in the classroom. In 2010, some pupils of Ayeduase Junior High School in Kumasi experimented to identify maths in traditional African music by using music to discover least common multiples.[21] Whiles this trial showed the possibilities of learning maths in aspects of African lives, an approach to teaching materials on fractals may provide ways for curriculum developers and teachers to tinker around how indigenous knowledge systems can be included in the Ghanaian syllabus.[22]

Ghana's pre-tertiary educational system follows a 6-3-3 primary, Junior High and Senior High School years respectively excluding the crèche/ kindergarten years. Although the early child years are important formative years, we are here concerned with the senior high school. In the current endeavour, high school syllabi and Core Mathematics in particular – with possible extension to Elective Mathematics – has been identified for the

[21] Eglash (2010) explains how traditional drumbeats and hip-hop effects helped teach the least common multiples.

[22] At the High School level, Ghana is part of the West African Examination Council (WAEC) which among other exams set the standard for the West African Secondary School Certificate Examination (WASSCE) in collaboration with the Ghana Education Service. Thus a consideration of fractals in the Ghana syllabus may in the near future help foreground aspects of transformative education in the WAEC syllabus.

inclusion of fractal knowledge in the curriculum in Ghana. Indeed the tertiary levels is crucial for education about fractals in Africa. The senior high level is however considered for two reasons: (1) the young minds that may continue to the tertiary may acquire the necessary foundation for advance tinkering with knowledge about fractals, (2) The student who may not reach tertiary level may still grasp the significance of this phenomenon in the African context in shaping their thinking and approach to society, the environment, nature and questions about the transformation of their country and Africa.

Attempting integration of Fractals in Core Mathematics/Elective Mathematics in Ghana.

Among the ten point aims of Ghana's Core Mathematics syllabus, it seeks to promote the use of mathematics in daily life, recognising and appropriating maths problem-solving strategies, developing abilities and important values such as confidence, tolerance and patriotism and appreciate linkages across disciplines (Ghana Education Service (GES), 2010). It is within this context that this paper suggest an inclusion of fractals in the core maths syllabus. Table 1 below follows the layout of the syllabus and suggests sections where fractal knowledge could be included.

Table 1. Proposed inclusion of fractals in high school mathematics syllabus. [23]

UNIT	OBJECTIVE	CONTENT	TEACHING AND LEARNING ACTIVITIES	EVALUATION
Unit 1.7.9 Plane Geometry	The student will be able to: Identity and draw irregular shapes in nature and African culture.	Fractals as irregular non-Euclidean shapes.	Let students as individuals and groups identify natural phenomena that give shapes other than Euclid geometry. Assist students to differentiate between fractals and Euclid geometry with diagrams. Eg. Regular triangle, versus triangles within triangles, circle versus circle of circles. 	Let students: Draw Fractal geometric figures applying the fractals principles of recursion, scaling, fractal dimension etc

[23] The first digit in the unit column indicate the year (SHS1, 2 and 3 respectively)

Unit 2.9 Mensuration	Calculate the area of a fractals	Area of a fractal system	Assist student to use the grid in fig 2.9.2 to determine the area of a fractal, fractal system or network[24]	Determine the quadrilaterals and triangles that can be drawn on the shape and use this information to find the area of an identified fractal E.g Koch Curve. 
	Find the fractal dimensions	Fractal Dimension and Scaling factors	Guide student to understand the Hausdorff-Besicovitch dimension (between integers)[25] Fractal dimension equation for D is given as the $\lim_{s\to 0} \frac{\log n}{\log 1/s}$ Or D= $\frac{\log n}{\log 1/s}$ Use the above formulae to calculate the scaling factors and attempt finding fractal dimensions and scaling factors in braids, basket nodes etc.	Find the fractal dimension of a Koch curve. n= units of line segment, s= scaling factor, D=dimension For a line segment of 4, and a scale factor of 1/3,[26] We have $4 = \frac{1}{(1/3)^D}$ Or $4 = 3^D$ Taking log of both sides $D = \log 4 / \log 3 \approx 1.26$

[24] Figure 2.9.2 is at Unit 2.9 of the High School Core Mathematics Syllabus (see GES, 2010).
[25] For the stepwise calculation of the fractal dimension see for example, Calculating fractal dimension. https://www.wahl.org/fe/HTML_version/link/FE4W/c4.htm
[26] Adapted from Calculating fractal dimension. https://www.wahl.org/fe/HTML_version/link/FE4W/c4.htm

Unit 3.1.2 Construction	Measure the length of open fractal shapes	Length of fractal shapes	Guide students to use a ruler or thread to measure the length of a fractal. E.g Adinkra symbol, Koch curve.	Determine the length of a fractal or fractal system.
	Develop fractals ruler and other construction tools	Fractal system	Guide students to develop the cantor set and create sets within infiniti. Students can also develop the human heart, or recursive adinkra designs, e.g Sankofa	Draw a fractal system using active and inactive loop principle
	Identify a scale drawing as enlargement or reduction using fractal dimensions	Transformations as fractals	Assist students to apply fractions in a scaling form to construct images and figures within the same figure/over the plane.	Use fractal scale drawing to enlarge, reduce or replicate a figure

Conclusion

African fractals are a central aspect of African knowledge systems which have yet to gain the necessary consideration in the corridors of education across the continent. This paper has showed the various principles and applications of fractals in the African ways of thinking and organising. The importance of understanding the connectivity and complexities that exist among humans and among humans and nature has been shown as a necessary task in the call to repair and rehumanize the planet earth.

In this period of urgent need for transformation in Africa, and at a time where there is instability in the global economic and political architecture, planning in Africa requires the embrace of the energies in the ideas of fractal wisdom and fractal optimism for the political reorganization of Africa and improvement in the livelihoods of the people of Africa.

In the final analysis, incorporating fractals in the knowledge production and distribution in Africa could contribute to efforts at reinterpretation of Africa, re-education, and correction of the effects of miseducation and misinformation about African knowledge systems which has partly contributed to the neglect in harnessing these indigenous knowledge systems for scientific, social, political and economic transformation in Africa.

Ghana's education system and the senior high school core mathematics syllabus provides a possible step for a practical teaching of fractals in Africa. It is hoped that this attempt at tinkering with the Ghanaian syllabus may promote further analysis and exploration to include other aspects of fractal education in the syllabi at pre-tertiary and tertiary level across Africa.

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