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Research Application Summary

A Mathematical Aso-Oke: Ndebele dolls, vertex-edge graphs, cryptology and number patterns in the lives of African Women in Agricultural Research and Development (AWARD)

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Abstract

The Mathematical Aso-Oke: Ndebele dolls, vertex-edge graphs, cryptology and number patterns in the lives of African Women in Agricultural Research and Development (AWARD) stems from work within the 2014 Carnegie African diaspora fellowship project, Culture and women's stories: A Framework for capacity building in science, technology, engineering and mathematics (STEM) related fields. This work is a collaboration between an African diaspora and African institutions focused at strengthening women capacities in Africa including, AWARD, Nigerian Women in Agricultural Research for Development (NiWARD), and Centre for gender issues in science and technology (CEGIST), University of Technology, Akure (FUTA). This article is founded on the CEGIST and personal stories of AWARD fellows showcasing their professional endeavors. The NiWARD in collaboration with the African diaspora has developed curricular materials for use in teaching mathematics in a gender-sensitive, multicultural manner that embraces leadership development, community building and entrepreneurship. The process uses the creative and innovative procedure of mathematical story-telling that makes visible significant aspects of the lives of these African female scientists who were chosen as AWARD Fellows. Mathematical story-telling uses mathematics tools, concepts, indigenous knowledge systems and cultural artifacts, viz, sculpturing of Ndebele dolls, to tell stories about people and communities.

Keys words: AWARD Fellow, capacity building, culture, gender equity and mainstreaming, mathematical story-telling, Ndebele people, Nigeria

Résumé

La mathématique Aso-Oke, les poupées Ndebele, les graphes de pointe, la cryptologie et les modèles numériques dans la vie des femmes africaines en Recherche et Développement Agricole sont issus du projet Carnegie de la diaspora africaine en 2014, Culture et histoires de femmes : Un cadre pour le renforcement des capacités dans les domaines liés aux sciences, à la technologie, à l'ingénierie et aux mathématiques. Ce travail est une collaboration entre

diaspora africaine et des institutions africaines basées sur le renforcement des capacités des femmes en Afrique, notamment AWARD, Nigerian Women in Agricultural Research for Development (NiWARD) et le Centre pour les questions de genre en science et technologie (CEGIST), Université de Technologie, Akure (FUTA). Le présent article est basé sur le CEGIST et les histoires personnelles des bénéficiaires AWARD présentant leurs efforts professionnels. Le NiWARD, en collaboration avec la diaspora africaine, a élaboré du matériel didactique pour l'enseignement des mathématiques dans une perspective multiculturelle et sensible au genre, qui englobe le développement du leadership, de la communauté et de l'entrepreneuriat. Le processus utilise la procédure créative et innovante de la narration mathématique qui rend visibles des aspects significatifs de la vie de ces femmes africaines scientifiques qui ont été choisies comme bénéficiaires d'AWARD. La narration mathématique emploie des outils mathématiques, des concepts, des systèmes de connaissances indigènes et des artefacts culturels à savoir la sculpture de poupées Ndebele pour raconter des histoires concernant les personnes et des communautés.

Mots clés: Bénéficiaire d'AWARD, renforcement des capacités, culture, équité genre, narration mathématique, peuple Ndebele, Nigeria

Introduction

African women in Science, Technology, Engineering and Mathematics (STEM) are an endangered group. They are significantly few, less than 1% of the African female PhD holders in the world. According to Wong (2015) in "Let Women Teach" women are an "at-risk" group in the teaching field. In the absence of effective strategies to re-engineer a change, this dreary trend shall continue. Becoming aware of career opportunities in STEM fields and the various pathways to success in these fields are helpful avenues for nurturing, grooming and mentoring African girls into STEM related fields and teaching, as well as, showing them how they can make positive contributions to society (Gordon, 2010). Also helpful for this type of nurturing of African girls is their understanding of the challenges experienced by successful African women in these fields. This mathematical profiling project which uses Ndebele dolls sculptures to profile African Women in Agricultural Research and Development (AWARD) Fellows who are winners of the AWARD prestigious program based in Nairobi, Kenya, provides a creative and innovative approach to re-engineering this change, based on stories of a subset of AWARD Fellows who are members of NiWARD.

Too often, successful and influential African women leaders and geniuses do not get the recognition they deserve. Their stories are usually invisible to people outside their realm of direct impact. This severely limits the effect of their biographies in nurturing, grooming and guiding young girls and others for leadership roles and success in their professional and personal endeavors (Agwu *et al.,* 2016). This mathematical story-telling project addresses this limitation by making visible biographies of a subset of NiWARD members within the context of teaching and learning mathematics.

In this era of globalization, African people face the urgent need to foster world-wide education about their mathematics, science, technology, history and culture (Gerdes, 1998). All groups of people have made significant contributions to the development of mathematics and other areas of STEM. However, the contributions of Africans other than those related to the early beginnings of Algebra and geometry in ancient Egypt, are still highly unacknowledged in the history of mathematics (Lumpkin, 1997). This is partly due to our oral traditions, slavery, colonialism, neo-colonialism, globalization, and the fact that our indigenous mathematics, scientific and technological knowledge as a people is often shrouded in our spirituality (Agwu, 2015). This notwithstanding, efforts ought to be made to document the mathematical contributions of Africans to enrich the curriculum in a multicultural and inter-disciplinary way by providing a wide repertoire of examples of mathematical concepts illustrated from an African context. Mathematical story-telling is an innovative procedure developed by Agwu (2014, 2015) that uses mathematical tools, concepts, indigenous knowledge systems and cultural artifacts including the sculpturing of Ndebele dolls, to tell stories about people and communities. This has been the focus of this project. This paper therefore shares the process, experiences and lessons of this innovative curriculum development engagement which is framed around the mathematical profiling of a subset of NiWARD members and the artistic doll-making culture of the Ndebele people.

Research Methodology

This mathematical story-telling and Ndebele dolls' project adopted a mixed methodological approach. It involved a compilation and analysis of biographies of the African Women in Agricultural Research and Development (AWARD) fellows and Nigerian Women in Agricultural Research for Development (NiWARD) members, together with initial mathematical story-telling explorations for interesting patterns, characteristics, relationships, community development activities, and work with rural women relevant to indigenous mathematics and scientific knowledge. Once these initial mathematical story-telling activities were completed, a subset of AWARD/NiWARD members were selected for further ethnographic study based on leadership characteristics, diversity of STEM related disciplines, community development activities that relate to farming and traditional work of rural women, as well as, indicators of motivation and inspiration of these women stories to students enrolled in MAT 200 – Introduction to Discrete Mathematics Writing Intensive class in Fall 2014 semester at Borough of Manhattan Community College, City University of New York.

For the subset of AWARD/NiWARD members selected, interviews with them and participant observation of their scholarly work and/or community development activities were conducted. Where scholarly work and/or community development activities related to traditional and cultural activities, study tours were made to relevant cultural and historical sites to learn more about the traditional and cultural aspects of their professional work and/or community development endeavors. The data collected through this procedure were analyzed for applications to various mathematical concepts to

determine how best it could be used in developing interesting and empowering curricular activities for the teaching and learning of mathematics based on African culture and women's stories.

After completion of the participant observation interview and analysis process, the process of curriculum development was initiated. This involved development of a pilot set of curricular activities, an exhibit of Ndebele doll sculptures of the selected subset of AWARD/NiWARD and complete mathematical stories of this selected subset. This was followed by field-testing and dissemination of the curricular activities and professional development on their use with educators at universities, colleges and schools and within workshops for primary, secondary, college and university students within STEM enrichment and research programs, in particular within the High school science and technology entry program and the MAT 200 – Introduction to discrete mathematics writing intensive course at the Borough of Manhattan Community College (BMCC), City University of New York (CUNY), for further assessment and refinement. The refinement process is ongoing with the goal of extending the work done to the NiWARD population.

Products and outcomes. Through this engagement, a range of products and outcomes including; mathematical stories, curricular activities and an on-line journal have been developed. Further, an exhibition of the sculptures of Ndebelle dolls created by a range of actors and the creation of alternative resources and courses are underway (Table 1).

Table 1. Products and outcomes of the project

Product/outcomes	Description
Digital and print publications.	The mathematical stories of and curricular activities developed for the selected subset of AWARD/NiWARD members are scheduled to be published online through the Drammeh Institute You Tube Channel and the Mathematics Teaching-Research Journal Online in 2017. In particular, the Drammeh Institute will be hosting a mathematical and digital story-telling program in April 2017 for high school girls who will be mentored in producing the mathematical stories to be published and who will field-test the developed curricular activities for further refinement. Print versions are scheduled to be published by the National Mathematics Centre (NMC), Abuja, Nigeria, in 2017. Additionally, the NMC will be hosting a mathematical and digital story-telling workshop in May 2017 for mathematics educators and high school girls

	who will engage also in field-testing the curricular activities for further refinement.
Three unique and beautiful exhibits of Ndebele doll sculptures symbolizing the selected subset of AWARD /NiWARD.	There will be three unique exhibits of Ndebele doll sculptures of the selected subset of AWARD/NiWARD created by high school and college students and educators. The Ndebele doll sculptures will picture vertex-edge graphs developed from their biographies. These Ndebele doll sculptures could be used as manipulatives for teaching concepts in graph theory and/or as musical African Shekere instruments for teaching and learning related to African music. The exhibit created by participants of the afore-mentioned April 2017 program of the Drammeh Institute will be on display there. The exhibit created by participants of the afore-mentioned May 2017 program of the NMC will be on display there too. The exhibit created by Borough of Manhattan Community College (BMCC), City University of New York (CUNY) students in MAT 200 – Introduction to Discrete Mathematics Writing Intensive Courses and the High school science and technology entry program in the 2014 – 2015 and 2015 – 2016 academic years will be on display at BMCC, CUNY.

Curricular activities that make visible successful African women in STEM and/or the STEM work of rural African women for use in teaching a wide variety of concepts in mathematics. These curricular activities after thorough field-testing and refinement through channels provided by the NMC, the Drammeh Institute and BMCC, CUNY will be used to create an Open and/or alternative resources (OER/AER) Discrete Mathematics course available through OER/AER BMCC, CUNY program for educators to access globally for use in teaching Discrete Mathematics.

Mathematics in and among the champions. Mathematics is in every action. It is a fact that in Africa the market women and their children operate their trade using principles of mathematics. This is why using the Ndebele indigenous mathematics concepts will be the background knowledge used in explaining the profiles of the selected subset of AWARD/ NiWARD. Hence, the reason to share the innovative process of mathematical patterns, polygons, graphs, symbols, counting principles and computations of the Ndebele people, which can be also be found on an Aso-oke. An Aso-oke is a colorful traditional hand woven Nigerian fabric usually woven by women and used as a head-tie. Since the selected

subset of AWARD/NiWARD hail from Nigeria, hence the connection to an Aso-oke. African youths, especially those in higher institutions, need to know this action for the future of our knowledge and development. A common thread among the AWARD/ NiWARD women for which sample curricular activities framed around them have been shared in this paper is that these seven women are champions in their community, apart from being successful in their professional fields. They are actively involved in mentoring and leadership development of other women and girls for success in their profession and active involvement in community development and other charitable initiatives that empower the lives of women and girls. They have built networks of women and girls within their sphere of influence who are making a difference in their communities.

Ndebele dolls symbolism in mathematics and relevance. The culture of the Ndebele people is highly rooted in mathematics. "A look at the Ndebele culture, especially at places like the Lesedi cultural village and the Botshabelo historical town expose the extent to which counting and numeration are used. They also show how members of such communities who have not been privileged to attend school are able to do most of the cultural activities and artefacts that are embedded with a lot of mathematical concepts and processes" (Mosimege, 2004). From their architecture to their clothing, jewelry and dolls, we see bright and colorful evidence of number patterns, geometric shapes, graphs, symmetric designs and other types of mathematical symbols. Ndebele people's "remarkable sense of symmetry and proportion illustrates the many mathematical formulas found in geometry and trigonometry" (News24, 2009). Hence, we can teach basic principles of mathematics through the art of sculpturing Ndebele dolls, simultaneously motivating interest and appreciation in students for mathematics and bridging the gap in resources for use in the teaching and learning of mathematics between rich and poor schools and/or schools in urban and rural communities. This project emphasizes the significance of integration of indigenous knowledge in the teaching and learning of mathematics. Additional, it emphasizes the applications of this type of teaching pedagogy for supporting or strengthening educational systems in rural and/ or poor communities and promoting small business entrepreneurship.

Sample of mathematics curricular activities. Seven mathematics curricular activities developed through this engagement include: (i) vertex-Edge graphs and number patterns; (ii) cryptography, digital root computation, and numerology; (iii) business mathematics, (iv) sequences, series, mode, number patterns, digital root computations and persistence number; (v) arithmetic; (vi) vertex-edge graphs, coloring, counting principles, sets, arithmetic, sequences, and series, and (vii) creative writing (Table 2). These activities are meant to expose students to real-life applications of and complex problem-solving related to a variety of mathematics concepts, reinforce their understanding of these concepts in the context of structural design, Ndebele art, and creative writing, while simultaneously learning a few important inspiring and motivating facts about the life of a given AWARD/ NiWARD woman.

Table 2. Sample mathematics curricular activities

Activity	Implementer	Description
Vertex-Edge Graphs and Coloring based on Ndebele Doll sculptures	Dr. Mojisola Olayinka Edema (AWARD/NiWARD)	This activity is designed to be used after students have learned the basic mathematical concepts about vertex-edge graphs and coloring maps and graphs. Through this activity, students will understand that in any person's biography exist different types of vertex-edge graphs. This activity involved the following: Examine the Ndebele doll sculpture at the center in Figure 1 and answer the following questions. This Ndebele doll sculpture represents the late Dr. (Mrs.) Mojisola Olayinka Edema who was born on August 1, 1968 and died on March 1, 2015. Dr. Edema was the former Acting Director of CEGIST FUTA, a founder of NiWARD and a traditional food microbiologist. She was a visionary and a reformer. She was a teacher, grassroots advocate, a community builder and a nation builder who always carried others along. She used her gifts to improve and enhance the lives of rural farmers in Nigeria (adapted from The Grace of Dr. Mrs. Mojisola Olayinka Edema, A visionary and a reformer, 2016). 1. Find the following vertex-edge graphs illustrated on this Ndebele doll sculpture in the center that represents Dr. Edema, state the number of edges and vertices of each graph, and identify whether or not the graph has been colored for its Chromatic Number: A. Path B. Cycle 2. Read and analyze the complete autobiography of the late Dr. Edema in the afore-mentioned book, The Grace of Dr. Mrs. Mojisola Olayinka Edema, A visionary and a reformer, 2016. Find other types of vertex-edge graphs in her life, such as a wheel and a complete graph. For the graphs you found, state the number of edges, vertices, and the degree of each of the vertices? 3. Based on your reading and analysis of the story of Dr. Edema in the book given in #2, can you find a vertex-edge graph that is an Euler circuit? 4. In addition to being a scientist, Dr. Edema was a wife, mother of three children, a woman with a talent for hairdressing, catering and food processing, and a business entrepreneur and owner of "BakeBites." Construct a vertex-edge graph that reflects the talents of Dr. Edema. State the type of vertex-edge graph you have constructed and color it for its Chromatic Number.

Cryptography, Digital Root Computation, Numerology and Ndebele Dolls	Nusirat Aderinsola Sadiku (AWARD/NiWARD)	Using the Cyphers given in Figure 2 and Figure 3, answer the following questions: 1. Write the name of the AWARD/NiWARD woman, Dr. Nusirat Aderinola Sadiku in Pythag-orean Cypher and in Caesar Cypher. 2. Write the phrase "Best Farmer of the Year" in Caesar Cypher and in Pythagorean Cypher 3. Decode the phrase "ZRPHQ IRU..FKDQJH" that has been coded using the Caesar Cypher. 4. Decode the sequence "595194" that has been coded using the Pythagorean Cypher. 5. The art of Ndebele people is very colorful. Now you have some basic knowledge of cryptography, develop a cypher based on color coding. 6. Construct an Ndebele doll sculpture of Dr. Nusirat Aderinola Sadiku that will carry a coded message of "Best Farmer" using the cypher you developed in #5.
Business Mathematics and Ndebele Dolls	Dr. Stella Williams (NiWARD)	This activity is designed to be used after students have learned the basic mathematical concepts about business mathematics and principles of accounting. It is geared towards teaching students certain economic and accounting principles of small business entrepreneurship with the goal of motivating them to consider starting an Ndebele doll production business. It also requires that students learn about the art of the Ndebele people and how to sculpt Ndebele dolls. A step-by-step process for sculpturing Ndebele dolls and the materials needed to engage in the sculpturing activity is provided in chapter IX of God's Own: The genesis of mathematical story-telling (Agwu, 2015).
Sequences, series, mode, number patterns, digital root computations and persistence number	Ogunlolu Omobolanle Temitope (AWARD/ NiWARD)	This activity is designed to be used after students have learned the basic mathematical concepts about sequences, series, digital root computation and measures of center. It is geared towards providing students with real-life applications of sequences and series that they can apply directly to themselves and learn about Numerological aspects of their life. 1. Convert the name Ogunlolu Omobolanle Temitope to a pythagorean sequence of numbers using the pythagorean cypher given in Figure 2. 2. Convert the pythagorean sequence in #4 to its associated pythagorean series. 3. What is the sum of the pythagorean sequence in #4? 4. What is the modal number in the Pythagorean sequence in #4? 5. From the above paragraph taken from the NiWARD autobiography of Ogunlolu Omobolanle Temitope in Edema, M., Williams, O. and Williams, S. 2013. What are some other significant numbers in her life identified in this paragraph? 6. Read the procedures given in chapter IX of God's Own: The genesis of mathematical story-telling by Nma (Beautiful) Jacob, a.k.a Dr. Nkechi Agwu, 2015 on how to compute the following numerological numbers: Life Path, Expression, Personality, Heart's desire,

		Birthday, Sun and Hidden passion. Compute these numbers for Ogunlolu Omobolanle Temitope and determine the persistence number for the digital root computations of these numbers.
Arithmetic and Ndebele Dolls	Dr. Olayinka Ogunsuyi, Ms. Olabukunola Williams and Dr. Nkechi Agwu (AWARD/NiWARD)	This activity is designed to be used after students have learned the basic arithmetic concepts of addition, subtraction, multiplication, division, ratios, rates and percent. It is also geared towards motivating students to engage in community service and charitable acts. The exercise for this activity involved: Dr. Ogunsuyi has 18 cowrie heads and 9 times more cowries than Ms. Williams. Using the Yoruba Conversion Rate for the Cowrie (40 cowries = 1 string; 2000 cowries = 1 head or 50 strings; 20,000 cowries = 1 bag or 10 heads), answer the following questions. 1. How many cowries does Ms. Williams have? 2. How many cowries in total do both Dr. Ogunsuyi and Ms. Williams have? 3. If Ms. Williams donates 10% of the strings of her own cowries to buy bags of garri to feed orphaned girls at Jacob's House of Dr. Agwu at Agbakoli Alayi in Abia State, Nigeria, how many strings of cowries is she left with? 4. If Dr. Ogunsuyi uses 20% of her cowries to purchase supplies for rural women in Akure in Ondo State, Nigeria to produce Black soap, how many cowries is she left with? 5. If a plot of farm land in Akure costs two strings, how many plots of farm land can Dr. Ogunsuyi buy with 50% of her cowries? How many plots of farm land can Ms. Williams buy with the remaining 90% of her cowries? 6. What percentage of cowries does Dr. Ogunsuyi have remaining after the purchase of Black soap supplies and farm land? 7. If Dr. Agwu is selling an Ndebele doll sculpture of Ms. Williams for a string, how many Ndebele doll sculptures of Ms. Williams can Dr. Ogunsuyi buy to donate as birthday presents for the orphan girls at Jacob's House of Dr. Agwu at Agbakoli Alayi in Abia State, Nigeria, with the remaining percentage of her cowries after the purchase of Black soap supplies and farmland?
Vertex-edge Graphs, Coloring, Counting Principles, Sets, Arithmetic, Sequences,	Dr. Joy Odimegwu (AWARD/NiWARD)	This activity is designed to be used after students have learned the basic mathematical concepts about vertex-edge graphs and coloring maps and graphs. It is geared towards facilitating student understanding of a picture as a map and that every map can be converted into its associated ver-tex-edge graph. It also requires that students know what an Okwe (Mancala) game looks like, learn about the art of the Ndebele people, and learn how to sculpt Ndebele dolls. A step-by-step

Series and Ndebele Dolls

process for sculpturing Ndebele dolls and the materials needed to engage in the sculpturing activity is provided in chapter IX of God's Own: The genesis of mathematical story-telling (Agwu, 2015).

This activity had the following essay and subsequent questions: "Mine is a farming family. My dad, Christopher Odimegwu God rest his soul though, an accountant by training, was very interested in farming while my mum Josephine Odimegwu is a home maker but she supported dad in his interest as a farmer. My parents got many acres of land in Enugu after my dad's retirement from Shell BP Port-Harcourt where he had worked for many years. They had a large poultry, piggery and cultivated cassava, yam, beans and tomatoes. As ours was a large family of eight children, four females and four males, being the fourth child and third female of the family, I was right in the middle… In December 2009, I was able to send off an abstract from my MSc. research work and it was accept-ed in an International Conference in Cairo, Egypt. AWARD sponsored my trip and this was my first International Conference and I had a wonderful time meeting top European and Arab scientists" – (adapted from Innovating the Rural space in Nigeria agricultural development, 2013). Based on the story of Dr. Joy Odigmegwu given above, answer the following questions.

1. Construct a family vertex edge graph for Dr. Joy Odigmegwu. Represent each member of the family with a vertex. Connect the two vertices that represent her parents with an edge. Connect with an edge the vertices that represent each child to the vertices that represent her parents. Connect the vertices that represent each child to the vertex of the child preceding and succeeding them in birth. Clearly label the vertices that represent Dr. Joy Odigmegwu and her parents.
2. Color the family vertex edge graph for its chromatic number and state the chromatic number.
3. How many subgraphs that are cycles with three vertices exist in this family vertex-edge graph of Dr. Joy Odigmegwu?
4. How many subgraphs that are wheels with four vertices exist in this family vertex-edge graph of Dr. Joy Odigmegwu?
5. Convert the picture in Figure 4 of the women farmers of Ossomala, Anambra State, Nigeria, and NiWARD woman and AWARD fellow Dr. Joy Odigmegwu into a vertex-edge graph by representing each woman with a vertex and connecting vertices of women touching each other by edges.
6. How many women, excluding Dr. Joy Odigmegwu, are in the picture in Figure 4?
7. Using the procedure outlined in Chapter IX of God's Own: The genesis of mathematical story-Telling by Nma (Beautiful) Jacob, a.k.a Dr. Nkechi Agwu, 2015 on how to create an

		Ndebele doll, create a set of Ndebele doll sculptures representing the women farmers in the picture in Figure 4. 8. If each woman in the picture in Figure 4 mentored two female farmers each year, how many female farmers in total would all of them have mentored in a decade? 9. If Dr. Joy Odigmegwu decided to build a female farmer mentee chain based on the holes in a 2x6 Okwe (Mancala) game board as follows: The 1st hole is for one female farmer that she mentors. The 2nd hole has double the female farmer mentees for the 1st hole. The 3rd hole has double the female farmer mentees for the 2nd hole. The pattern of doubling mentees in succeeding holes based on preceding holes continues till you get to the 12th hole. How many female farmer mentees would Dr. Joy Odigmegwu have on the 12th hole? How many female mentees would she have from the 1st to the 12th hole? See Figure 5 be-low for an illustration of an Okwe game board. 10. What type of sequence is described in #9 and how many terms does this sequence have?
Creative Writing Project	Dr. Nkechi Agwu	This activity is designed to be used after students have learned basic mathematical concepts related to geometry, the art of mathematical story-telling and the process of creative writing. It is geared towards providing students with the opportunity to write mathematical feature stories about people and communities in a creative manner. 1. Research, read and analyze a biography of a woman from the set of NiWARD, either at http://www.niward.org or from the book, Innovating the rural space in Nigeria Agricultural Development, 2013, and/or from elsewhere. Engage in the type of creative writing illustrated in Figure IX to tell a mathematical story of the woman's life. 2. What other polygonal figures are illustrated on the columns in the Coronation Hall in the Deji of Akure's Palace in the picture in figure IX, other than triangles? 3. If each triangle on the column represents a plot of community farmland in Akure Kingdom, suppose the smallest triangle has dimensions of height as 100 feet and base as 50 feet, what is the perimeter and area of this smallest plot of community farmland?

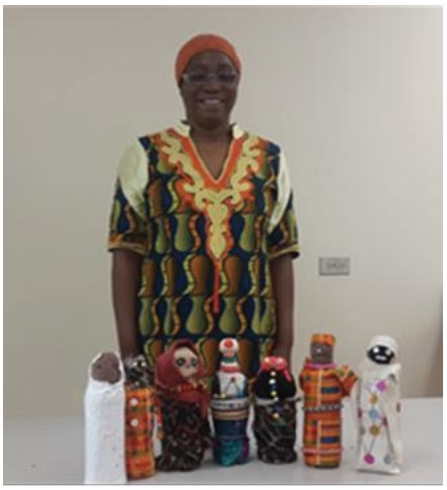

Figure 1. Seven Ndebele Doll Sculptures representing: Dr. Mojisola Edema, Dr. Joy Odigmegwu, Dr. Omobolanle Temitope Ogunlolu, Dr. Olayinka Ogunsuyi, Dr. Nusirat Aderinsola Sadiku, Ms. Olabukunola Williams and Dr. Stella Williams.

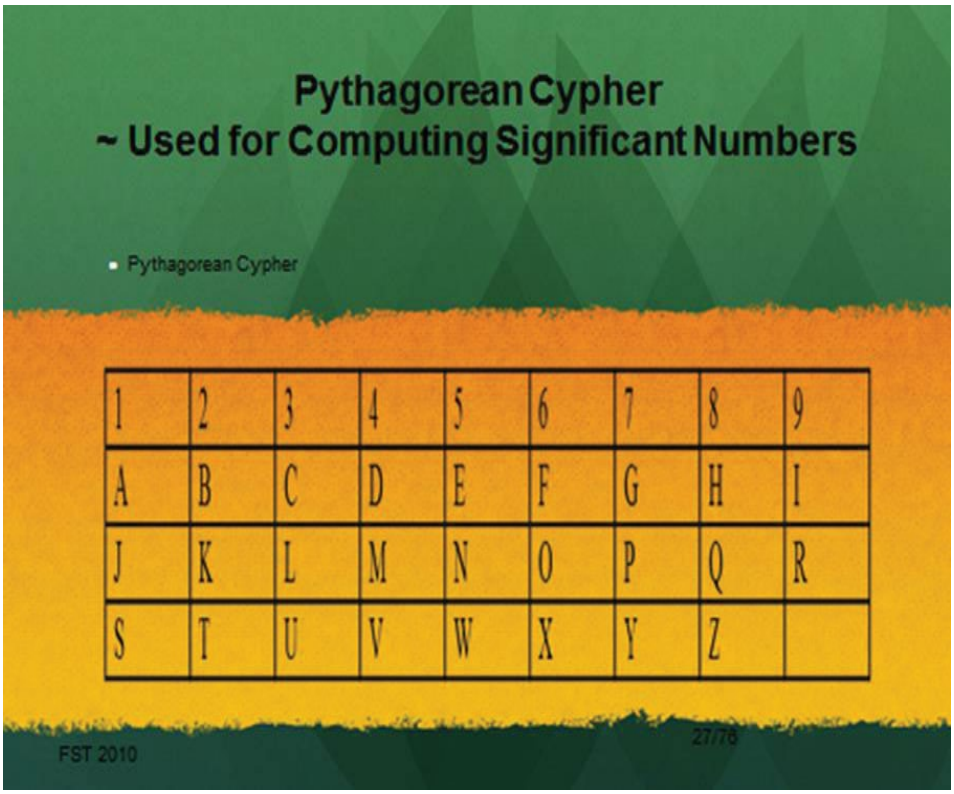

Figure 2. Pythagorean Cypher

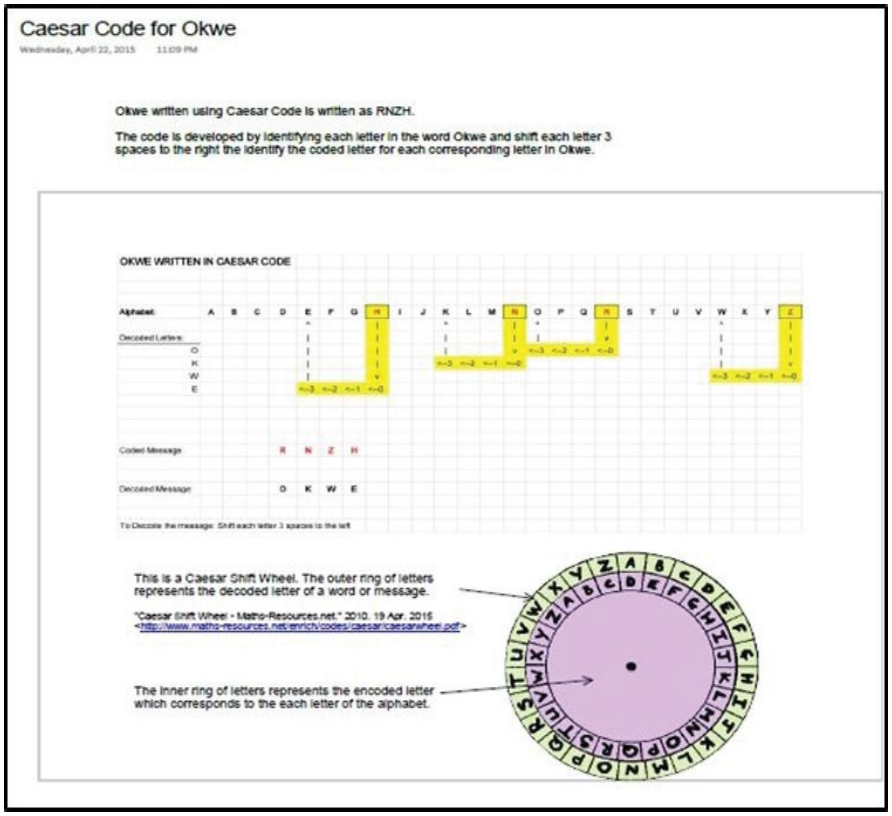

Figure 3. Caesar Cypher

Figure 4. Women Farmers of Ossomala in Anambra State, Nigeria, with NiWARD Woman and AWARD Fellow Dr. Joy Odimegwu

Figure 5. The Columns in the Coronation Hall of the Deji of Akure Kingdom, Ondo State, Nigeria, Illustrating Geometric Symbolism

Relevance of Ndebele dolls symbolism pedagogical approach

This pedagogical approach integrating indigenous mathematical knowledge and women's stories has a high potential for promoting gender equality in STEM (Science, Technology, Engineering and Mathematics) and students understanding of issues related to under-representation and diversity, as well as, facilitating educational and economic empowerment of women and indigenous groups that are virtually absent from the curriculum. It can help to bridge the resource gap of between poor and rich school districts through the creation of Ndebele dolls for use in teaching and learning mathematics made from recycled and readily available materials.

Through the use of this type of curricular activities, student will see real-life applications of vertex-edge graphs evident in the biography of a person and reinforce their knowledge about vertex-edge graphs and coloring principles. They will learn how to analyze and interpret a person's biography mathematically, as well as, compute the numerological pattern of a person's life that can be used to determine certain aspects of a person's life. They will learn how to develop presentations to tell stories about the life of a person using the tools of mathematics.

This unique and innovative pedagogical approach provides students with functional and vocational education that has the potential to empower them to be creative, innovative, become small business entrepreneurs, engage in community service, and promote charitable work for the under-privileged and less fortunate. The Ndebele doll sculpturing creative process, will help students to see beauty in diversity, appreciate it, and understand issues related to it based on the different types of dolls created and who they symbolize. Students will be provided with lessons on how to developing a financial production and sales cost model for an Ndebele doll sculpturing business. Students will learn about different cultures of the world as the doll sculpturing activities can be

adapted or modified or extended to include the creation of dolls from different cultures of the world. Hence, they will be empowered to address global challenges and compete effectively in a global world.

Discussion

The Ndebele people are an ethnic group in the Southern part of Africa whose life style is highly rooted in mathematics, viz., geometry, number patterns, vertex-edge graphs, symmetries, and so on. However, one will hardly find examples taken out of their life in mathematics text-books. They use dolls in highly significant ways. For instance, when an Ndebele woman would like to give birth to a child, she will create a doll and name the doll. When she finally gives birth, the child will be named after the doll. Also, when an Ndebele man is interested in marrying a woman, he will create a doll and give it to her instead of giving her an engagement ring to symbolize that the woman is in a committed relationship leading up to marriage. Adaptations of these two aspects of their cultural use of dolls are embodied in this project. The creation of an Ndebele doll named after and symbolizing an AWARD woman represents the birthing of that AWARD woman into the family or thought process of the creator of that Ndebele doll. The Ndebele doll of the AWARD woman symbolizes a committed relationship of the creator of that Ndebele doll to tell mathematical stories of that AWARD woman. In telling a creative mathematical story of an AWARD woman with the use of an Ndebele doll sculpture symbolizing her learning of the mathematical concepts reflected within this activity is reinforced. Creators of Ndebele dolls symbolizing an AWARD woman are now empowered in making connections to real-life in the area of literature (biography), art (sculpturing), culture (Ndebele culture) of those mathematical concepts. In so doing, they can begin to extend their connections to other fields as they have had the experience of doing so in the afore-mentioned fields. Additionally, the creator of that Ndebele doll is gradually being nurtured, groomed and mentored informally about a particular STEM related field, what it takes to be successful in that field and the challenges that one might face to achieve their professional goals in that area.

Conclusion and way forward

A variety of mathematics curricular activities using a similar approach to the sample of seven given above have been developed and framed around a subset of AWARD/NiWARD members as described within the research methodology. These activities provide visibility and recognition to these women while simultaneously facilitating the teaching and learning of various concepts in mathematics and highlighting different STEM related careers as a means of nurturing, grooming and mentoring young women and girls to consider these careers. They are currently being field-tested for further refinement by partnering organizations. Africa needs to use cultural, creative and innovative methods as illustrated above to profile women and girls for further empowerment and sustainability of agricultural processes and other areas of STEM. Thus, this work with

AWARD/NiWARD members is a new development that will improve the teaching of mathematics in Africa, as well as, the transformation of agricultural researches leading to sustainable agricultural development in the 21st century. More importantly, so that the African Agriculture sector can feed Africa and the rest of the world as well as the Higher Education that will 'Empower Women and Youths' to become positive and significant participants in the newly approved 'Sustainable Development Goals' that is replacing the just concluded 'Millennium Development Goals.'

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