Research Collaboration in Mathematical Applications and Innovations to Solve Community Challenges: A Position Paper

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Abstract

The U.N. General Assembly has declared, through its 2030 Sustainable Development Goals, to transform the world. This can be achieved through enhancing scientific research, among other things. Following suit, Zimbabwe strives to attain a middle economy status by the year 2030. In this regard, Zimbabwean researchers and academia will be required to produce quality goods and services that contribute to the viability and sustainability of the communities and the country at large. Regarding academia, the basis for the promotion of university lecturers in Zimbabwe is now the Philosophy of Education 5.0 system, which is centered on five pillars, which include teaching, research, community service, innovations, and industrialization. To achieve this philosophy, this position paper which focuses on STEM subjects but is more biased towards mathematical thinking and learning argues for research collaboration and high impact research, especially research that helps to solve community challenges. It also challenges the readers and researchers to offer practical solutions to some chosen problems in the STEM disciplines and concludes by suggesting strategies of forming research groups or 'collaborations,' especially during conferences or workshops, and recommends that institutions should adequately fund high impact research. Points and suggestions raised in this paper can apply to other countries too, especially those with developing economies.

Keywords: research collaboration, STEM, mathematical applications, mathematical innovations, community challenges, high impact research.

1.0 Introduction

The U.N. General Assembly has declared, through its 2030 Sustainable Development Goals, to transform the world (United Nations General Assembly, 2015). Following suit, Zimbabwe strives to attain an upper-middle economy status by the year 2030 (Government of Zimbabwe, 2018). In this regard, its people including academia, will be required to produce quality goods and services which contribute to the viability and sustainability of the communities and the country at large. Regarding academia, the basis for the promotion of university lecturers in Zimbabwe is now the Philosophy of Education 5.0 system which is centred on five pillars which include teaching, research, community service, innovations and industrialisation (Jonathan, 2018).

This paper which focuses on Science, Technology, Engineering and Mathematics (STEM) subjects but is more biased towards mathematical thinking and learning argues for the issues of research collaboration (Section 2), and high impact research (Section 3), especially research that helps to solve community challenges. It also argues for mathematical applications and innovations (Section 4) and challenges the academics and researchers to offer practical solutions to some chosen problems in the STEM disciplines (Section 5), and recommends strategies for forming research groups or 'collaborations' especially during conferences or workshops where different people meet, undertaking inventions and innovations and funding high impact research (Section 6).

2.0 Collaboration issues addressed in this paper

This paper which is theoretically as well as practically oriented addresses the following aspects of collaboration and gives some examples:

1. What is research collaboration?
2. The need for collaboration,
3. Benefits of research collaboration,
4. How to collaborate,
5. Collaboration as gleaned from SAARMSTE Aims, and

6. SAARMSTE patterns of research collaborations for 20 years (1999-2019).

2.1 What is research collaboration?

The Cambridge dictionary says to collaborate is to "work with someone else for a special purpose" (https://dictionary.cambridge.org/dictionary/english/collaborate). Hence in research collaboration has the following meanings or interpretations:

- Offering general advice and insights to someone doing research,
- Actively participating in a specific piece of research,
- Performing parts of a project separately and then integrating the results (Katz and Martin, 1997).

Research collaboration is not synonymous with but can be measured by multiple authorship or co-authorship of papers (to improve the quality of the research). This is so because '… some kinds of research collaborations do not result in co-authored publications and reversely some co-authored publications cannot mirror the actual situation of research collaborations (Chen, Zhang and Fu, 2019, p.162). It can also be measured relatively using interviews, questionnaires or anonymous posts.

2.2 The need for collaboration

The need for collaboration can be aptly illustrated by the following viewpoints:

a) United we stand and divided we fall.

b) 'Rume rimwe harikombi churu'- For example, the saying '*rume rimwe harikombi churu*' ('one man cannot encircle a mound alone' - which means that one person cannot do all things alone) is intended to foster the spirit of working together and helping one another, be it in the field or elsewhere, to produce enough food to feed the people. (Chirume, 2018, p.93).

c) The 'nhimbe' concept**-** *Nhimbe* (an indigenous collaborative work system) promotes community responsibility, sharing, togetherness, mending and promoting community relations and helping one another to produce more for families and the community (c/o: *zunde ramambo*- the chief's granary). *Nhimbe* promotes community security and sustainability rather than individual welfare (https://www.accord.org.za/conflict-trends/nhimbe/).

d) In academia, it is often said that if one does not publish, then one perishes. But to publish, one needs to research first. So if one is a novice in research, one needs someone else to assist him/her - hence the need for collaboration.

2.2.1 Setbacks

However, some factors negatively impact on research collaboration. "Not only do increased administrative burdens and committee obligations discourage academics from research, but the long and discouraging processes of getting research projects approved and getting ethical clearance also hinder academics who are eager in doing research" (Wolhuter, 2018, p.18).

Zimbabwean academics are poorly or not at all funded to carry out research, and that is why research productivity is low (Thondhlana and Chirume, 2016). Wolhuter (2018, p.16) states that "The low levels of funding available for education research in South Africa and the resultant small-scale scope of most research projects in education… are other reasons for the low research output." High impact research can pay bigger dividends if there is thorough planning, adequate funding and sometimes collaboration.

2.3 Benefits of research collaboration

Wagers (2013) lists 20 benefits of collaboration some of which are: higher impact publications, encourages greater and more creativity, less work, (positive) criticism, quick peer review, a wider array of techniques, efficient learning, deeper research, increased number of publications, patents, funding (impressing investors), knowledge of what others are doing, less risk, networking (better and more concrete networks), and early adopters. He says that collaboration partners are 'early adopters' for one's approach or method, new technology or new hypothesis. Published materials that result from collaborations also have a higher likelihood of being sold for

profit since researchers need money from royalties. Such funds can also be used to conduct more and other researches. Further to that, Kishk Anaquot Health Research (2008, p. 1) says:

Truly collaborative research involves respecting and understanding the participants and recognizing the knowledge and capabilities of the local people who can work with researchers to obtain analyses and solutions. It should be viewed not only as something that should be done for ethical reasons, but also as a way to improve the quality of research.

2.3 How to collaborate

Here I list some ways by which researchers, in mathematics and statistics or other areas, can collaborate and I call them collaboration models:

Collaboration based on research designs (Quantitative, Qualitative or Mixed Designs)

In a single research project or multiple projects, one team could work on quantitative designs, the second team on qualitative designs while the third one could work on mixed designs. The results and findings could then be merged in a single report or different reports.

Collaboration based on branches or sub-branches of mathematics or mathematics education

Researchers can form teams based on their skills and knowledge in the different branches or sub-branches of mathematics. For example, one team could tackle issues to do with Arithmetic, one on Algebra, one on Geometry, one on Trigonometry, one on Calculus, one on Statistics, and one on Probability.

Collaboration based on researchers' desire or interests

For instance, researchers can form teams based on their desire, interests, experience and expertise in using some statistical software to analyse data. Some people are good at using software such as SPSS, Mathlab, GenStat, Minitabb or G.I.S. The results that emanate from 'expert' use of the software enhance the quality of the research product.

Collaboration based on STEM subjects

For countries such as Zimbabwe to attain an upper-middle economy status by the year 2030 and for them to compete favourably with other countries in this modern technological age, their schools and colleges should give more prominence to the teaching and learning of STEM subjects. Hence researchers can form collaboration teams based on STEM subjects. One team could focus on science, one on technology, one on engineering and another one on mathematics as they are applied in a creative and innovative way to solve problems – the end result being the production of quality goods and services that help to boost the economy. As an example one could refer in this paper to Section 5 on 'Putting Theory into Practice.'

2.5 Collaboration as gleaned from SAARMSTE Aims

SAARMSTE stands for Southern African Association for Research in Mathematics, Science and Technology Education (https://www.saarmste.org/). As an academic, a researcher and a member of SAARMSTE, I was motivated by the association's programmes and activities over the years and then thought of crafting this position paper. Many academics and researchers the world over can attend and present papers at SAARMSTE conferences. The aim of SAARMSTE is to advance research in mathematics, science and technology education (hereinafter "MSTE") in Southern Africa by:

- fostering a sense of community among researchers in MSTE;
- promoting research to improve and develop MSTE programmes in response to current and future needs;
- seeking representation in relevant MSTE policy-making bodies;
- organising conferences at which the results of MSTE research can be presented;
- assisting in the development of research skills of people interested in entering the MSTE field, and developing further expertise in that field by means of organizing workshops, short courses and exchange visits;
- liaising with other MSTE bodies;

- providing avenues for local publication of the findings of research in MSTE;
- making research in MSTE available and accessible to policy makers and practitioners;
- building an open forum for debate encompassing different MSTE research paradigms;
- encouraging discussion and research around key issues in MSTE; and
- through other means as the members in a general meeting may determine

(https://www.saarmste.org/about/overview).

It can be noted that within SAARMSTE's aims attempts at collaboration are rife. For instance, *fostering a sense of community, assisting in the development of research skills, liaising with …, building an open forum for debate,* and *encouraging discussion***…**, are cases in point.

2.6 SAARMSTE patterns of research collaborations for 20 years (1999-2019): An analysis of the Proceedings

By counting and assessing the authorship of abstracts and books of proceedings of SAARMSTE, I came up with patterns and statistics of SAARMSTE research collaborations since 20 years (1999-2019), and these are presented in Table 1 below.

Table 1

Year	Single author	Collab (2)	Collab (3)	Collab (4)	Collab (≥5)	Venue	Paper Type	Total
1999	24	12	6	2	12(et al)	UZ	Conf Pper	56
2000	49	14	10	3	5(5), 2(6)	U of PE	Conf Pper	83
2001	40	13	7	4	4(5)	Ed Mondl	Conf Pper	68
2002	34	24	10	11	3(6), 1(7) 2(8), 1(9)	U of Natal	Conf Pper	86
2003	59	32	7	18(4+)	0	Swaziland	Conf Pper	116
2004	59	49	20	5	3(5), 2(6)	Cape Tow	Conf Pper	138
2005	32	19	8	4	2(5), 2(6) 1(8), 1(9)	Namibia	Conf Pper	69
2006	50	25	10	2	1(5), 2(6)	Pretoria	LP, SP	90
2007	35	12	3	1	1(5), 2(6) 1(8)	Ed Mondl	LP, SP	55
2008	18	19	10	6	0	Lesotho	LP,SP	53
2009	106	64	24	7	1(8)	Rhodes	LP, SP	202
2010	71	59	21	3	0	UKZN	LP, SP, SS, S, R	154
2011	66	52	18	0	3(5), 2(6) 1(7)	North West Univ	LP	142
2012	16	26	9	2	0	Malawi	LP	53
2013	63	72	25	4	1(5), 1(6) 1(7)	UWC: C/T	SP, LP, R, SS, W, S	171
2014	7	6	2	0	0	NM Met U	LP	14
2015	8	18	3	1	0	Ped & Ed Mondl Univ	LP	30
2016	18	19	3	1	1(7)	Tshwane	LP	42
2017	10	10	3	0	1(6)	CUT (FS)	LP	24
2018	7	9	1	0	0	Botswana	LP	17

2019	65	84	42	15	4(5)	UKZN	LP, SP, P, S, SS	210

Key: Conf Pper=Conference Paper, LP=Long paper, SP=Short paper, P=Poster, S=Symposia, SS=Snapshot, R=Round table, W=Workshop

The types of papers started just as conference papers and were later divided into short papers, long papers, symposia, snapshots, posters, roundtable papers and workshop papers. The definitions for these types of papers can be accessed from the SAARMSTE website (www.saarmste.org). In 1999, some twelve papers had the authorship of one member and others (et al.) hence the exact number of authors who had written the papers could not be established.

An analysis of the numbers in Table 1 above was done using Microsoft Excel 2016 and seven figures (Figure 1-Figure 7) were produced.

Figure 1 is a line graph which shows the actual time series and linear trend of the total number of papers presented in each year over the years 1999-2019.

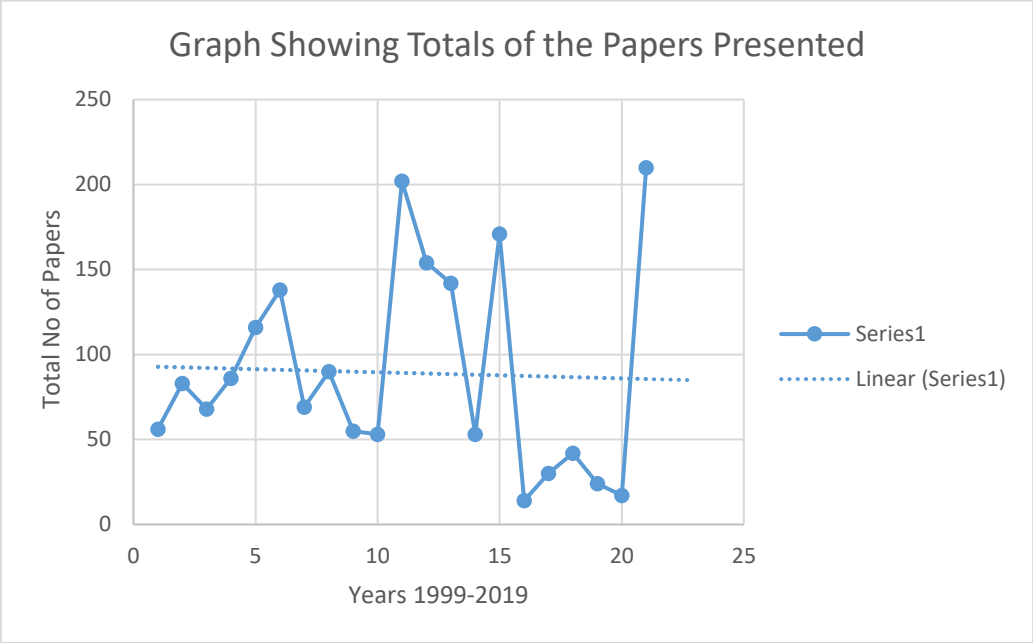

Figure 1: Totals of the papers presented

From Figure 1 above it can be observed that the total number of SAARMSTE papers started low (at 56 in the year 1999) and fluctuated but then relatively increased since then. The lowest were in the years 2014 and 2018. However, the linear trend shows a somewhat steady decline with the 'average' number of papers being below 100.

Figure 2 shows the time series and linear trend for single authorship of the papers.

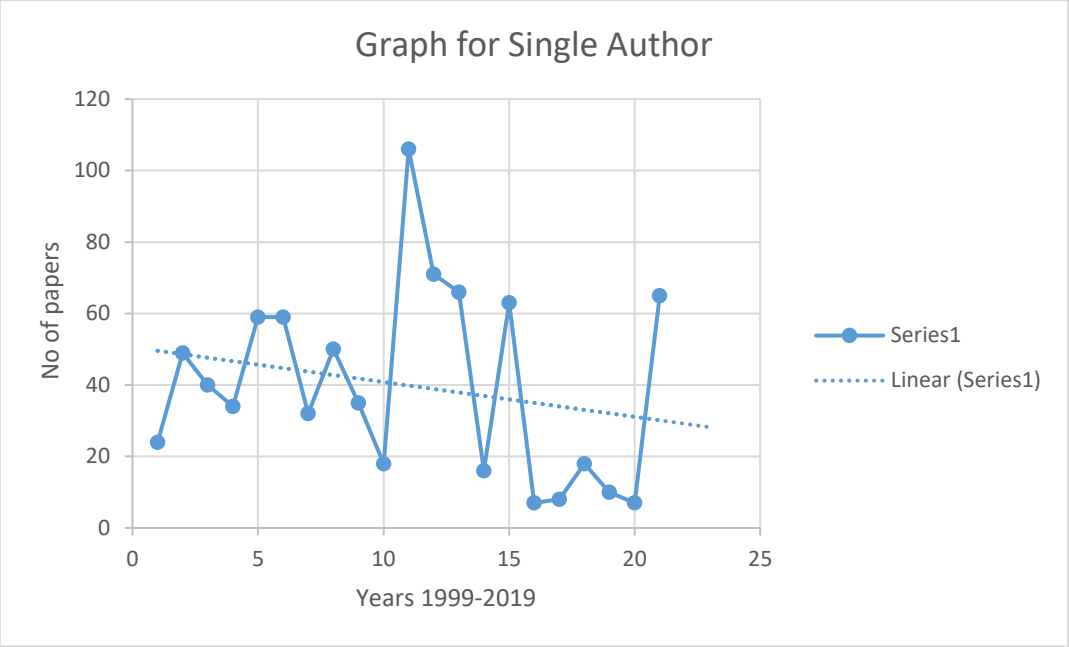

Figure 2: Graph for Single Author

Figure 2 shows that there was a peak of single authorship papers in the year 2009. The linear trend shows that the single authorship papers declined in number.

Figure 3 shows the pattern for two authors.

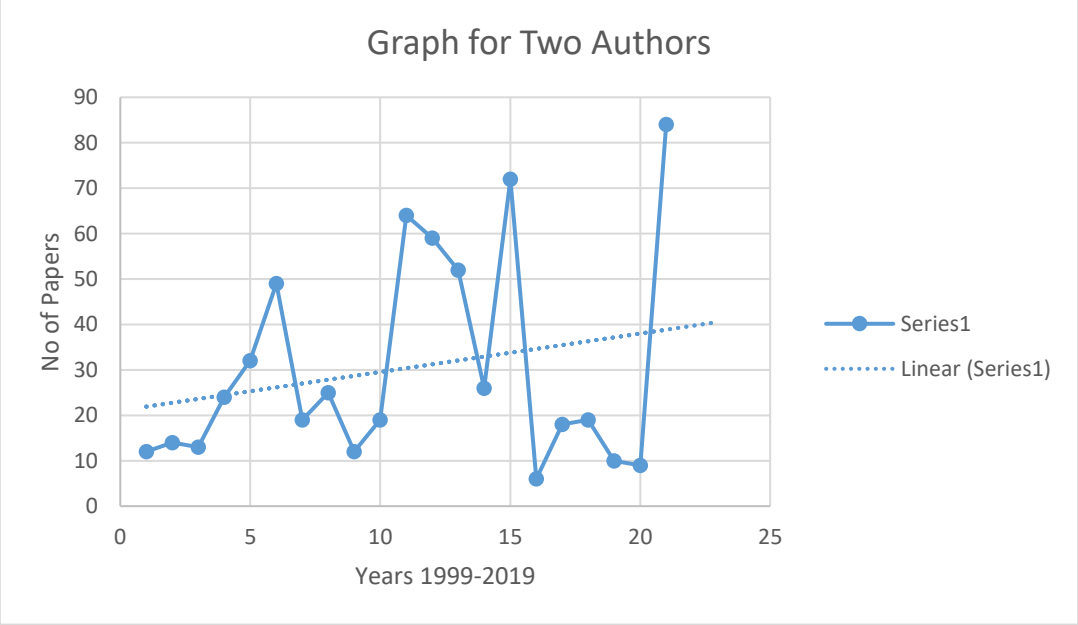

Figure 3: Graph for Two authors

In Figure 3 one observes that there was generally an increase in the number of papers prepared by two authors. It is however, not mandatory for both authors to attend the conference and co-present their paper since only one author, if need be, could present. Figure 3 also shows that research collaboration by two people was somehow on the increase.

Figure 4 below shows the pattern for three authors which is more or less the same as for two authors (Figure 3).

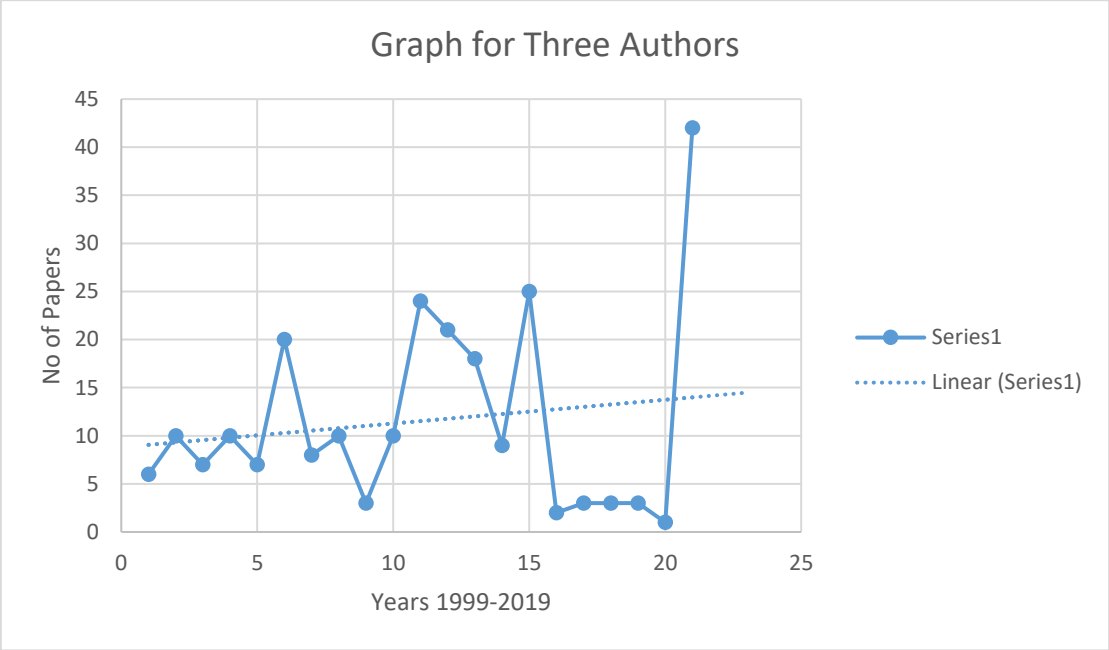

Figure 4: Graph for Three Authors

Figure 5 shows the pattern for four authors.

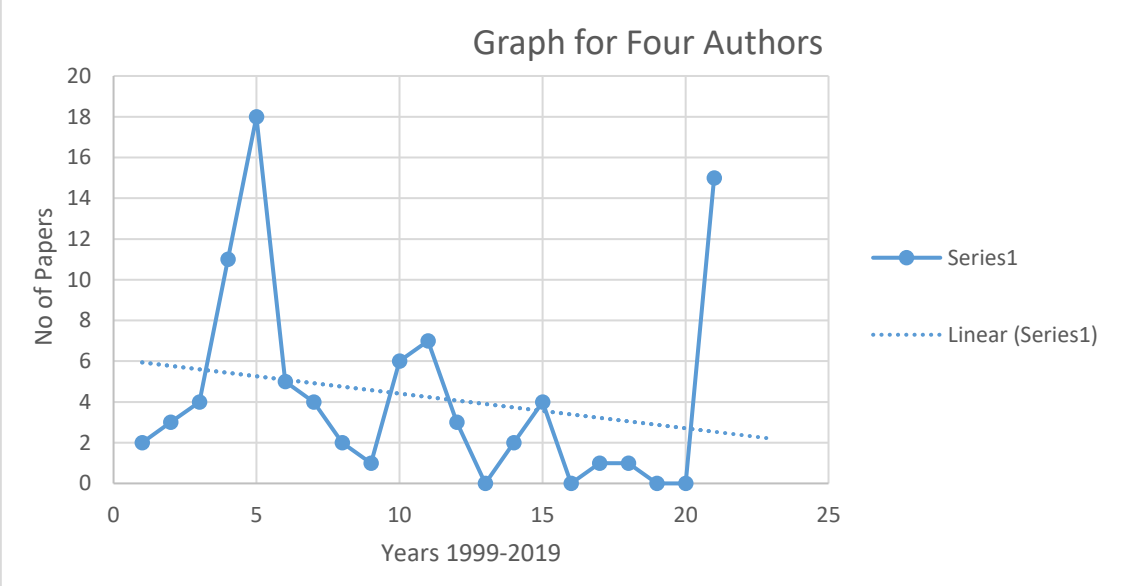

Figure 5: Graph for Four Authors

Rather interestingly for Figure 5, there was a peak of 18 and 15 papers authored by four people and presented in 2004 and 2019 respectively. However, the general linear trend shows that the number of papers authored by four people is rather declining.

Figure 6 shows the pattern for five or more authors.

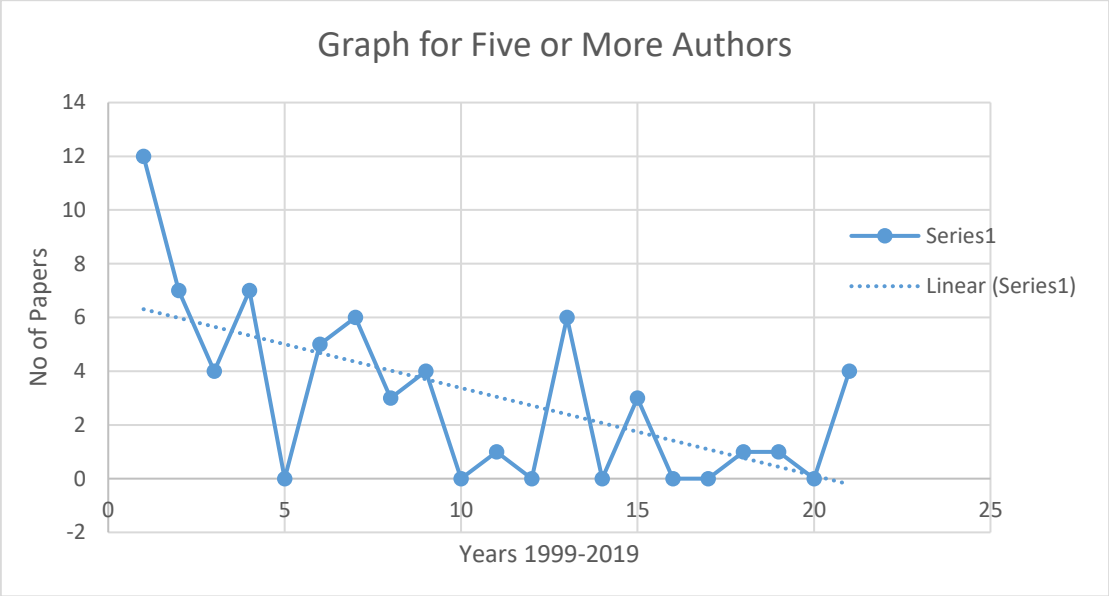

Figure 6: Graph for Five or More Authors

One could infer, from the actual time series in Figure 6 that the number of papers authored by five or more people has been declining. The linear trend shows this scenario more vividly. Figure 5 also shows the same pattern (or decrease) though not as sharp as in Figure 6. This probably means that it could be prudent for collaboration teams to be small in number (maybe 2 to 3 or 2 to 4 but not more). This could however depend on the time, size, cost and importance attached to the project.

For comparative purposes Figure 7 shows all the SAARMSTE collaborations since 1999-2019. It shows comparatively the line graphs for the number of papers authored by one, two, three, four and five or more authors (Series 1, Series 2, Series 3, Series 4, and Series 5, respectively).

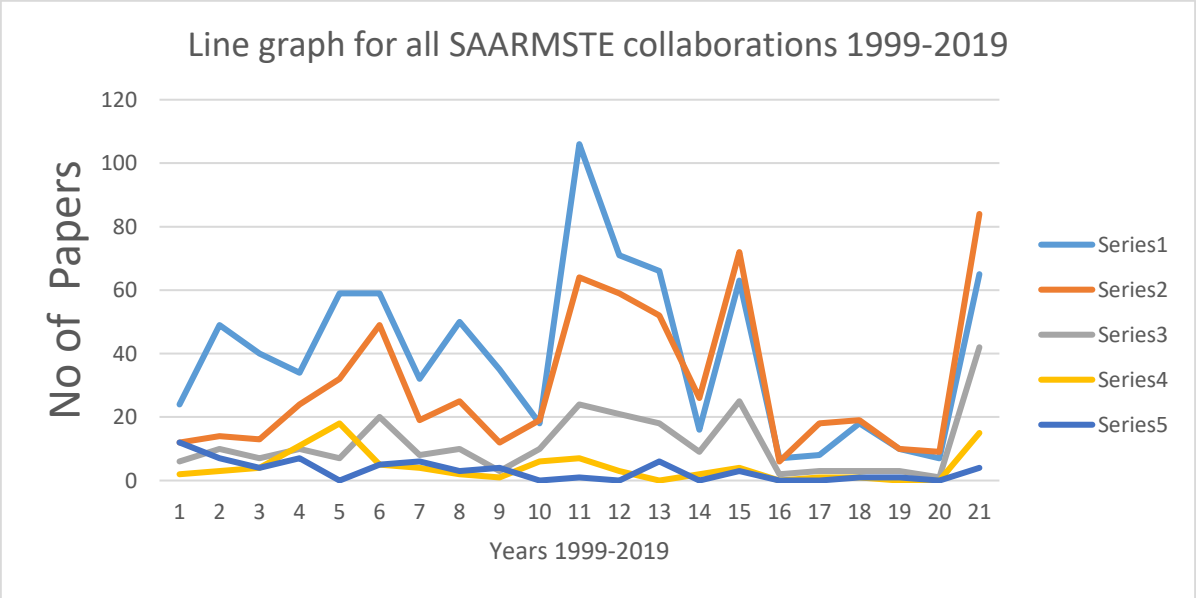

Figure 7: Comparative Line Graphs

As seen from Figure 7, one notes that on the whole, single authors presented more papers than two authors; who also presented more papers than three authors and so on up to a very small number of papers presented by five or more than five people. Also as mentioned before, one notes that more papers could be produced by collaboration teams of small rather than large numbers.

3.0 High Impact Research

According to https://en.oxforddictionaries.com/definition/impact, impact means having 'marked effect or influence.' The impact can be viewed in two ways, viz. theoretical impact and practical impact (Wolhuter, 2018). This paper argues that while both 'theoretical impact' and 'practical impact' types of research are important and useful it is high time that university lecturers in Zimbabwe and elsewhere should focus more on the practical one to produce 'tangible' goods which help to sustain communities. Such practical research can be in the form of patentable research or 'cutting-edge-community-oriented' research.

3.1 Patentable research

Patentable research is research that is new, useful and non-obvious (Patent Researching 101, n.d.). Also Statutory law, per §35 U.S.C. 101 (United States Patent and Trademark Office, 2015, p.20) defines a patent in the following way: "Whoever invents or discovers any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof may obtain a patent therefore, subject to the conditions and requirements of this title." High impact inventions and innovations should not be hidden from others but should be patented and also shared with others through collaborations, and knowledge and technology transfers (Geuna and Nesta, 2004).

3.2 Cutting-edge-community-oriented research to sustain (local) communities or to solve community challenges

First, I define a community challenge as a problem affecting or negatively impacting (in the short or long term) the community, needing to be solved with their cooperation and up to their satisfaction. Then, I hereby give a few examples of what I consider as community challenges:

3.2.1 A certain 'unfamiliar' disease has recently affected a significant number of cattle in the community but there is no known remedy at hand.

3.2.2 There has been a persistent drought in a certain village over the past few years. The Agricultural demonstrator has suggested that a small dam be built at the only one possible place which is, however, too close to three adjacent households, too close to their ancestors' graves and on the other side of the small river bed also close to their vegetable gardens.

3.2.3 Due to unknown factors to the local school authorities, secondary school students continue to dislike, fail and drop mathematics in large numbers and this has negatively impacted on (a) tertiary institutions' enrolment (b) employers' recruitment of mathematically qualified personnel and (c) parents' income and expenditure patterns. A group of mathematics education researchers have been challenged by the local authorities to critically examine and evaluate the current mathematics school curriculum and give recommendations.

3.3 The need to solve community challenges

Community challenges should be solved or alleviated to ensure cohesion of the community, for viability and sustenance of the community, for the community to end up helping other communities or organisations. For example, a teachers' organisation in Zimbabwe such as ZIMTA could help and work with another Zimbabwe teachers' organisation such as PTUZ, or SAARMSTE could work and collaborate with similar African associations such as CEMASTEA (Kenya), SAASTE (South Africa) and (SMASE-WECSA (for Western, Eastern, Central and Southern Africa). In the same vein, N.G.O.'s should not only donate goodies and money but should practically work hand in glove with local communities in order to share knowledge and skills that would result in the viability and sustainability of the community.

4.0 Mathematical Applications and Innovations

Theoretical knowledge that is divorced from practice has limited use. Freire (2005) advocates for humankind to unite theory with practice (reflection and action) in order to transform the world. In his book 'Pedagogy of the Oppressed' he says, "But human activity consists of action and reflection: it is praxis; it is transformation of the world. And as praxis, it requires theory to illuminate it. Human activity is theory and practice; it is reflection and

action" (p.125). Praxis is, "reflection and action upon the world in order to transform it" (p.51). "For apart from inquiry, apart from the praxis, individuals cannot be truly human" (p.72).

Thus theoretical mathematical knowledge can and should be used in applications and innovations to solve community challenges for the betterment of the community as a whole and for the betterment of others too. Practical activities, knowledge and real-life products also can be used to generate theory. Here I give examples of mathematical applications and innovations that can help to solve community challenges. The examples are based on observations of real life situations in Shurugwi district of Zimbabwe:

Problem: There is a problem of water shortage in Juchuta community of Shurugwi district. The community includes a primary school, secondary school, two churches, shops, a clinic and four nearby villages. Humans and animals suffer from thirst, hunger and disease, especially in the dry season.

Solution: A proposed solution is to build a water weir/dam at a sited place (map or plan to be provided).

Activities to achieve the objective:

- Finding carrying capacity/volume of water weir/small dam.
- Brainstorming and forecasting on hazards to nearby households if dam overflows.
- Brainstorming and forecasting on hazards to nearby environment/flora/ if dam bursts, for example, soil erosion and how to control it.
- Discussing and suggesting how to rescue humans and animals if and when they drown.

Other purposes of the study/project:

- To model the problem and proposed solutions using G.I.S. or Geogebra software.
- To equip Juchuta Secondary School 'O' level students with G.I.S. or Geogebra simulation and modelling skills.

Methods to be used and Materials required:

(Materials) - Geogebra and G.I.S. software, internet, pens, pencils, paper, laptops, cell phones- for taking photos and videos.

(Methods) - The following methods may be used so that the project becomes successful, is beneficial to and is 'owned' by the community members themselves.

- Facilitator/researcher selling/marketing the project to community members,
- Selected community members to be interviewed on their opinions, worries and suggestions regarding this project,
- Facilitator/researcher demonstrating, interviewing, coaching and illustrating information to some community members and students,
- Students sharing notes on challenges and proposed solutions,
- Students in groups reporting back, illustrating and demonstrating, sketching and making some write-ups,
- Selected community members and some students to voluntarily work on the project and get some small incentives, if need be, and
- Facilitator/researcher to do data presentation, analysis and compile a write up.

5.0 Putting theory into practice

I now challenge academics and researchers, and other people interested in research collaborations to 'put theory into practice' by actually doing the following STEM related activities and report the results at their gatherings. Results can also be posted to skchirume@gmail.com**.**

5.1 The small group activities

Group A: Biology/Chemistry oriented-

5.1.1 Muhabhurosi or muhingi (African Mulberry or *Morus mesozygia* Stapf) fruit is delicious, has nutritional and health benefits to human beings. For example, it is widely used to make pies, sweet dishes (tarts), wines,

cordials (drinks) and herbal teas. It is also used to cure heart diseases, diabetes, anemia, and arthritis. It improves digestive health, lowers cholesterol, and improves immunity. However, it ripens only once a year (in May). How can we make and preserve *muhabhuros*i fruit drink so that it can be drunk when off-season?

5.1.2 Makavhu/mapudzi (Bottle gourd or calabash cucumber- *Lagenaria siceraria*) has nutritional as well as health benefits (e.g., Vitamin C (13.00%), Zinc (7.36%), Potassium (3.70%), Vitamin B6 (3.54%) and is good for skin health and cardiovascular health. They lower stroke, treat cancer, prevent colds and flu, and are good for hormonal balance. They grow well and in abundance in many districts of Zimbabwe but they do quickly become hard and lose their freshness and taste (*kukomba*). How can we store fresh ones so that we can eat or sell them after a long time and when off-season?

Group B: Physics and Engineering oriented-

5.1.3 During Cyclone Idai many bridges were washed away by heavy rains and people could not visit some places to check on the welfare of their relatives. Discuss how you can make strong and durable foot-bridges using cheap and locally available materials. Make sketch notes or small models.

Group C: Mathematics and Technology oriented-

5.1.4 Geogebra is free software for teaching and learning Mathematics. It has been translated and used in more than 40 languages (excluding ChiShona and IsiNdebele). Discuss how you would translate Geogebra software into ChiShona (or IsiNdebele). Give some examples of Shona/Ndebele terms translated from English**.**

5.1.5 People have been queuing at the bank to get cash BUT this has resulted in them getting more stressed and losing time to work and get more money. Design a mathematical model that minimises the time one stands in a queue at the bank, that reduces stress and that maximises profit or amount of money one would earn. [Suppose the people who queue are all teachers].

6.0 Way Forward

I round up this paper by giving the following suggestions or ways forward.

- Universities and other institutions of higher learning should provide adequate support and funding if academics and researchers are to realise Philosophy of Education 5.0 and to produce high impact research. As a starting point, there is need for academics to Form Research Groups NOW.
- Collaboration should be facilitated. For example, at a research conference or workshop a paper can be circulated where participants fill in their Name, Cell Number, e-mail address, Research area/interests, and Comments and Suggestions. The conference facilitators should then use this information to form research teams. At the next coming conference feedback or 'report backs' could be given. There is need to access and share information of what other people are doing in a particular field of research so that potential collaborating partners at the national or international level can be identified. In Zimbabwe, such knowledge can be accessed from the National Research Database of Zimbabwe (NRDZ) (http://www.rcz.ac.zw/nrdz/about-nrdz/).
- Mathematicians and Mathematics Education researchers should not only engage in theoretical research but should also research on mathematical applications, innovations and inventions which help to solve community challenges. They should put theory into practice by implementing their results and findings.
- Points and suggestions raised in this paper can apply to other countries too, especially those with developing economies.

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