Promoting Invention And Innovation In STEM Education By The Integration Of Makerspaces In Zambian Secondary Schools: STEM Teachers' And Pupils' Perceptions

Moses Kayola Phiri, Vincent Chinyama, Lex Rourke, Jack George Jumbe

Chiwala Provincial Stem Secondary School,
PO Box 71526, Ndola, Zambia Contact: +260967517357,
kayolamoses@yahoo.com

St. Marcellin's Secondary School,
PO Box 260209, Kalulushi, Zambia Contact: +26072828615,
vincentckchinyama@gmail.com

STEMTronics-STEM Education and Innovation Consultants
PO Box 70810, Ndola, Zambia: Contact 00260760744303,
rourkelex@gmail.com

The Copperbelt University, School of Mathematics and Natural Sciences,
PO Box 21 692, Kitwe, Zambia Contact: +260 966 909 905,
Jack.jumbe@cbu.ac.am

Abstract: This study focussed on STEM teachers' and pupils' perceptions on the concept of integrating makerspaces in Zambian secondary schools to promote 21st century skills such as innovation. Despite gaining a lot of traction in most developed countries, the concepts of STEM education and makerspaces are either missing or given very little attention in most African countries. Critical case sampling, a type of purposive sampling was used for this study. The target population was selected based on the researchers' inferences that they might represent a broader trend. Out of all the teachers who handle STEM related subjects on the Copperbelt Province of Zambia, only 53 teachers who attended the ZASE conference were included in the survey. 60 pupils who participated in the provincial JETS fair competition were targeted to represent all the STEM pupils on the Copperbelt Province. For teachers, a structured questionnaire with ordinal scaling questions was used to collect data and a questionnaire with structured ordinal scaling questions and open-ended questions was used to collect data from pupils. Quantitative descriptive statistics and qualitative methods were used for data analysis. The study established that STEM teachers and pupils were limited in their awareness on the concept of makerspaces in STEM education and their experience in making STEM-related products. It further established that STEM teachers and pupils would strongly recommend the integration of makerspaces in Zambian schools to promote the development of invention and innovation skills in learners. They perceived the concept of integrating makerspaces in Zambian secondary schools to be highly beneficial to learners.

Keywords: Innovation, invention, makerspaces, STEM education.

1.0. INTRODUCTION

STEM education (this study uses the term 'STEM education' to simply refer to the education of STEM-related subjects such as integrated science, physics, chemistry, biology, ICT, agriculture science, design and technology, food & nutrition and mathematics in Zambian secondary schools and not the purposeful integration of the Science, Technology, Engineering, and Mathematics disciplines, with the objective of solving real life world situations as postulated by Ramli et al. (2017)) is expected to equip learners with 'invention' and 'innovation' skills. However, STEM teachers in the developing world often avoid using heuristic strategies in the classroom and prefer a more ostensive approach (AAAS, 2002) due to lack of proper training in presentation of practical work to students and also the lack of necessary apparatus and equipment. As a result, for many students, what goes on in the laboratory contributes little to their learning about science. Practical work is often characterised by 'cookery-book' procedures in which students merely carry out instructions from textbooks. STEM education, which is expected to be 'fun' has been turned into a 'chalk and talk' approach where 'minds-on' is emphasised rather than 'hands-on'. All stakeholders concerned with STEM education in Zambia are aware of the situation such that it has become a 'song' on annual national conferences held by Zambia Association for Science Education (ZASE) and the Zambia Association for Mathematics Education (ZAME). To overcome this problem, in 2019, Zambia started developing the internationally recognised STEM education as an interdisciplinary approach to education that applies concepts of Science, Technology, Engineering and Mathematics (Ramli et al, 2017). A pilot STEM curriculum was designed and implemented in 52 selected secondary schools across Zambia. However, due to a number of factors such as teachers' lack of understanding of STEM education, teachers' lack of preparedness to implement STEM education and lack of facilities, materials and equipment in most selected schools, STEM education was halted in May of 2021 (Magasu et al, 2022). According to Magasu et al (2022), teachers claimed not to receive enough training on how to handle STEM education and yet the Zambia Education Curriculum Framework (2013) has demands that are similar to those of STEM education. For instance, the ZECF (2013) demands teachers to provide holistic science education which can lead learners to acquire key competences of which 'innovation skills' are part. Currently, Zambia has no 'formal' STEM education, hence the 'informal' STEM education being discussed in this study. Internationally, research has shown that the 'maker movement' is spicing up STEM education as it suggests that maker-centred learning activities attract greater numbers of learners to get interest in STEM content areas and 'making' reinvigorates both teachers and learners (Oliver, 2016a, 2016b; Peppler & Bender, 2013). Makerspaces or maker labs are integrated in schools in most developed countries (Dougherty, 2016; EU, 2018). A makerspace, also known by the name "maker lab" is a concept that has been gaining traction as part of the maker movement over the past several years. Makerspaces, at their core, are community spaces with resources for "making." These spaces can be in their own unique location or can be integrated into libraries or classrooms. A makerspace is an area with open space for people to gather and create. In some countries maker labs are used to enhance science education as they give learners an opportunity to make any science project using a combination of sciences. They are considered to be an additional lab to traditional labs such as computer, physics, chemistry, biology and agricultural science labs. They are spaces for application of science concepts. Makerspaces also allow the collaboration between STEM teachers and experts in a variety of fields related to STEM subjects. On the Copperbelt province of Zambia, Chiwala Provincial Stem Secondary School is successfully doing a trial of the STEM electronic maker lab as depicted in Figures I to VI.

FIGURE I: *Chiwala Provincial Stem Secondary School makerspace*

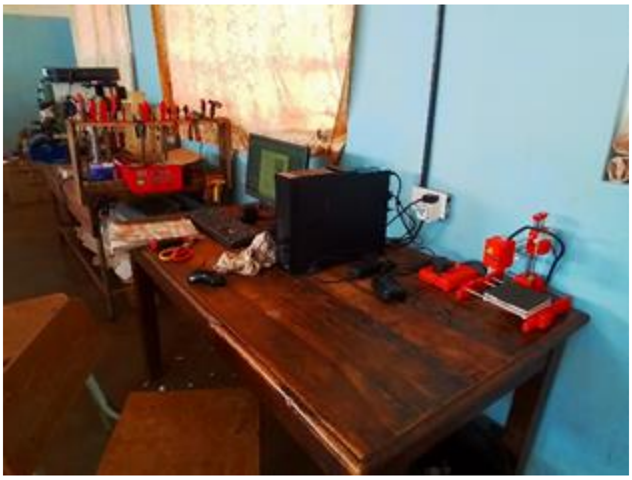

FIGURE II: *E-waste for use by learners when making STEM products*

FIGURE III: *Some of the tools used by learners to make STEM products*

FIGURE IV: *Learners engaged in the making process*

FIGURE V: *An external expert in electronics facilitating learners' innovations*

FIGURE VI: *Display board of electronic circuit components*

This study investigated the awareness of STEM teachers and pupils about the concept of 'integrating makerspaces in STEM education' on the Copperbelt province of Zambia. It even investigated STEM teachers' and pupils' experience with making of STEM related products. The study also sought to get a glimpse into STEM teachers and pupils' perceptions about the benefits of integrating makerspaces in STEM education. It further investigated whether STEM teachers and pupils would be interested to integrate makerspaces in their secondary schools so as to promote 'invention' and 'innovation' in STEM education. This was cardinal as it would facilitate the effective implementation of STEM education which is engaging to students and promotes the acquisition of 21st century skills of 'invention' and 'innovation'.

2.0. BACKGROUND AND FRAMEWORK

STEM education plays a critical role in economic development. Most African nations have vast natural resources and yet lag behind in economic development (Namayanga & Banda, 2021). The biggest gap lies in the education system that is producing students lacking the necessary STEM skills to convert the vast natural resources into finished products. An unprecedented number of African children complete secondary school without skills of 'invention' and 'innovation' despite being exposed to STEM education. The World Bank Group report analysis (Makhtar, 2017) asserts that the central reason for this situation in most poor countries- **is that they want jobs**. **Good education** is simply considered to be **a way to get better jobs.** This view of education is right except that it is not suitable in the 21st century. As pointed out in the World Bank report analysis (Makhtar, 2017), '**across the developing world, there simply aren't enough jobs for young people coming out of school'** regardless of the quality and level of education. **There is need for more job creation, not only the creation of microenterprises, small businesses that employ just one or two people** (Makhtar, 2017). Hence the need for **'invention'** and **'innovation'** skills. African countries need to do a lot of investment in research and development so as to promote educational systems that are favourable for equipping learners with innovative skills. The 'maker movement' is one area in which African nations can invest. Developed nations have done a lot of investments in the maker movement (Dougherty, 2016). In the United States, K12 educational institutions integrate makerspaces with emphasis on STEM content areas (Oliver, 2016a; Peppler & Bender, 2013). Makerspaces strengthen learning in STEM subject matter by reinvigorating both teachers and learners (Schad & Jones, 2020). Learning in makerspaces is through construction of artifacts. Such kind of learning is 'fun' and supportive of innovative skills. The current maker movement is based on the education theory of 'constructionism' by Semour Papert where 'learning is done by constructing knowledge through the act of making something shareable' (Martinez & Stager, 2013). Makerspaces focussing on STEM subjects can help foster a link between education, innovation and industry, as well as real-world applications (EU, 2018). Makerspaces create an environment for people to come together to create and invent things and learning occur during the making process. (Kurti et al., 2014). Unlike experiments in school laboratories which require learners to execute a ready-made script, makerspaces allow learners to display their creativity and innovation (Blikstein & Krannich, 2013). Formative assessment can be used to enhance the integration of makerspaces in STEM and should focus on the process and not products (Gomes, 2016). STEM makerspaces, also known as maker labs foster innovation through hands-on experimentation, allow learners to move from an abstract concept to a real-world understanding, allow learners learn how to make failure into a learning experience, provide learners with the opportunity to learn something new and promote a wide range of 21st century skills in learners (Bevan, Petrich, & Wilkinson, 2014; Hsu, Baldwin, & Ching, 2017). Makerspaces are diverse in nature and can involve a wide range of stakeholders. This study is restricted to STEM makerspaces or maker labs integrated in the education of STEM content areas in secondary schools. As can be noted from research, there is a strong link between the integration of makerspaces in schools and the development of invention and innovation skills in learners (Bevan, Petrich, & Wilkinson, 2014; Blikstein et al, 2017; Baldwin, & Ching, 2017; Martin, 2015; Schad & Jones, 2020). Despite the 'maker movement' being popular in developed countries, literature based on the concept had nothing concerning the deliberate integration of makerspaces in schools of poor African countries. This is in opposition to the features of African indigenous education such as 'putting emphasis on practical learning' where making was a continuous part of learning (Mushi, 2009).

3.0. METHODS AND SAMPLE

3.1. SAMPLE AND BACKGROUND

Critical case sampling, a type of **purposive sampling** was used for this study. The target population was selected based on the researchers' inferences that they might represent a broader trend (Black, 2010). Out of all the teachers who handle STEM related subjects on the Copperbelt Province of Zambia, only 53 teachers who attended the ZASE (Zambia Association for Science Education) conference were included in the survey. This group was representative of all STEM teachers in the province as most of them are either highly experienced or heads of Science Departments in their respective schools. 60 pupils who participated in the provincial JETS (Junior Engineers Technicians and Scientists) fair were targeted to represent all the STEM pupils on the Copperbelt Province. This was a representative group in that these pupils were considered to be the best in STEM related subjects from all the ten districts of the province.

3.2. DATA COLLECTION

For teachers, a **structured questionnaire** with **ordinal scaling questions** was used to collect data. The questions focussed on the;

i. STEM Teachers' general awareness on the concept of integrating makerspaces in secondary schools.
ii. STEM Teachers' general experience with making products in their STEM subject.
iii. STEM Teachers' perception of the benefits of makerspaces on STEM learners.
iv. STEM Teachers' recommendation on the integration of makerspaces in secondary schools.

A **questionnaire** with **structured ordinal scaling questions** and **open-ended questions** was used to collect data from pupils. The questions focussed on the;

i. STEM pupils' general awareness on the concept of integrating makerspaces in secondary schools.
ii. STEM pupils' general experience with making STEM related products.
iii. STEM pupils' perception of the benefits of makerspaces.
iv. STEM pupils' recommendation on the integration of makerspaces in secondary schools.

3.3. DATA ANALYSIS

The data which was numerical and ordinal in nature, was statistically analysed using the Statistical Package for the Social Sciences (SPSS) to obtain frequency distributions for each of the responses on the Likert scale of the data. Frequency tables and bar charts were used to display the data meaningfully. Qualitative content analysis was used to analyse pupils' comments from the open-ended question. Just as Marrying (2000) has described QCA, the pupils' comments were classified into categories derived from areas of interest. NVivo was used in qualitative content analysis.

4.0. RESULTS

Figures VII to XXXIV are horizontal bar charts showing the percentages of responses from the questionnaire items as analysed using SPSS version 28.

4.1 STEM TEACHERS' GENERAL AWARENESS ON THE CONCEPT OF INTEGRATING MAKERSPACES IN SECONDARY SCHOOLS

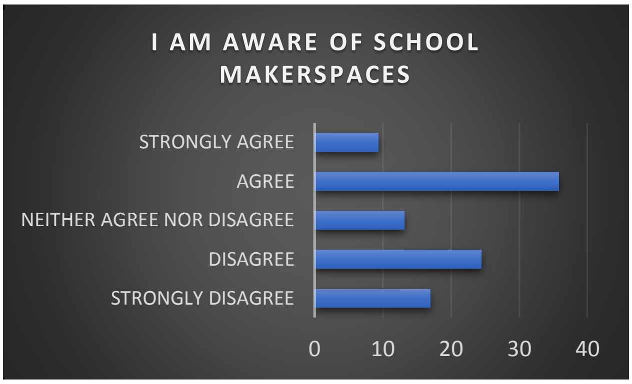

FIGURE VII. *Teachers' questionnaire item 1 results*

4.2. STEM TEACHERS' GENERAL EXPERIENCE WITH MAKING PRODUCTS IN THEIR STEM SUBJECT

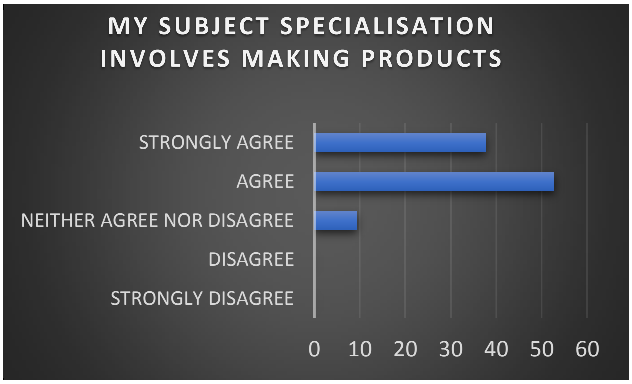

FIGURE VIII. *Teachers' questionnaire item 2 results*

FIGURE IX. *Teachers' questionnaire item 3 results*

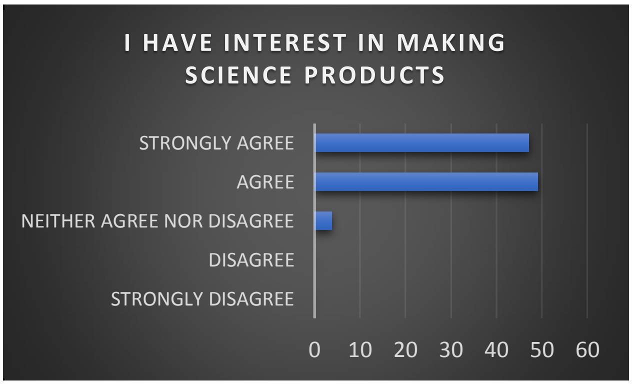

FIGURE X. *Teachers' questionnaire item 4 results*

4.3. STEM TEACHERS' PERCEPTION OF THE BENEFITS OF MAKERSPACES ON LEARNERS

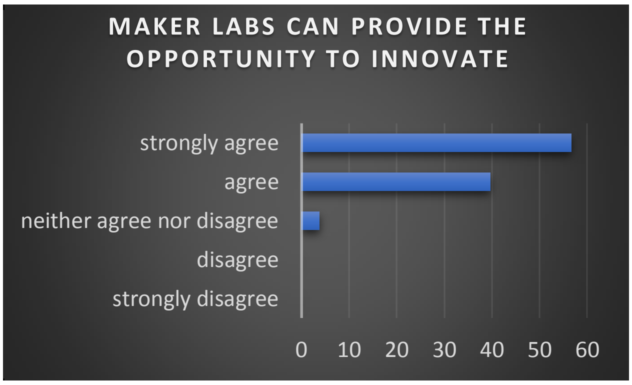

***FIGURE XI**. Teachers' questionnaire item 5 results*

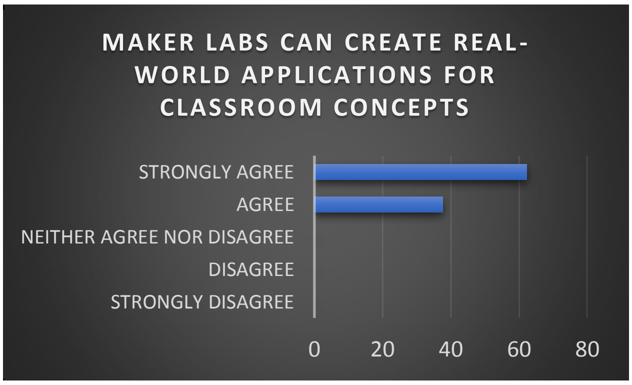

***FIGURE XII**. Teachers' questionnaire item 6 results*

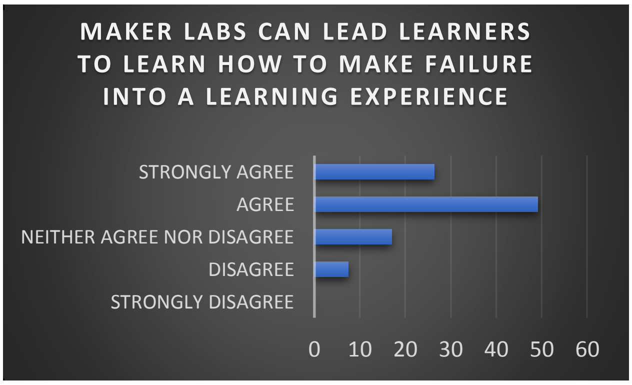

***FIGURE XIII**. Teachers' questionnaire item 7 results*

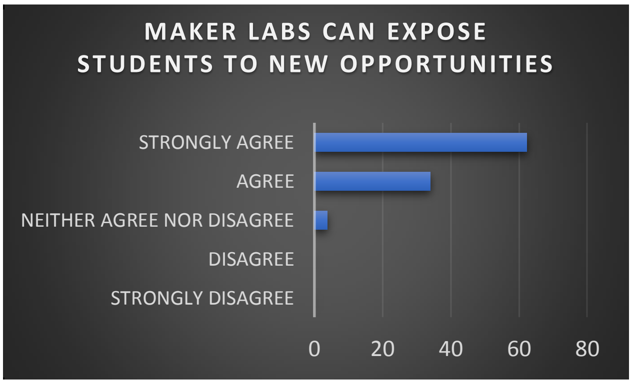

***FIGURE XIV**. Teachers' questionnaire item 8 results*

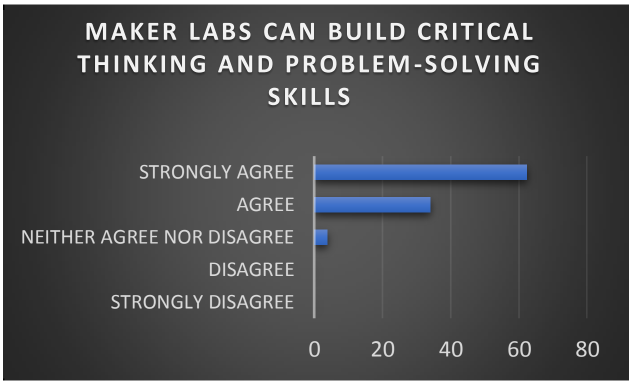

***FIGURE XV**. Teachers' questionnaire item 9 results*

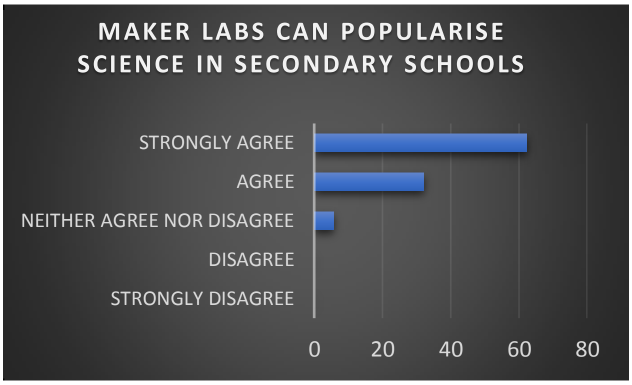

***FIGURE XVI**. Teachers' questionnaire item 10 results*

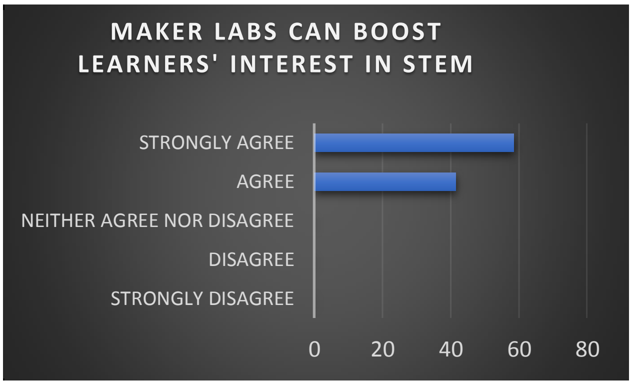

***FIGURE XVII**. Teachers' questionnaire item 11 results*

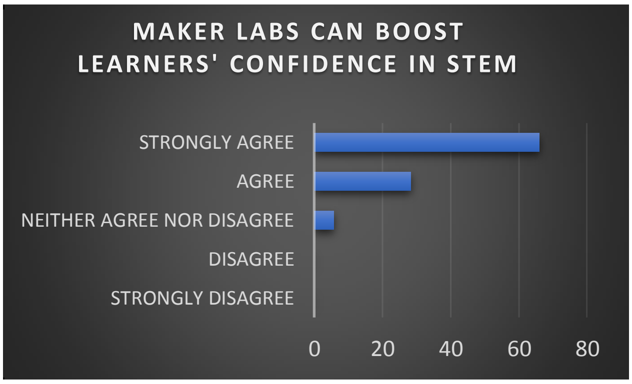

***FIGURE XVIII**. Teachers' questionnaire item 12 results*

4.4. STEM TEACHERS' RECOMMENDATION ON THE INTEGRATION OF MAKERSPACES IN SECONDARY SCHOOLS

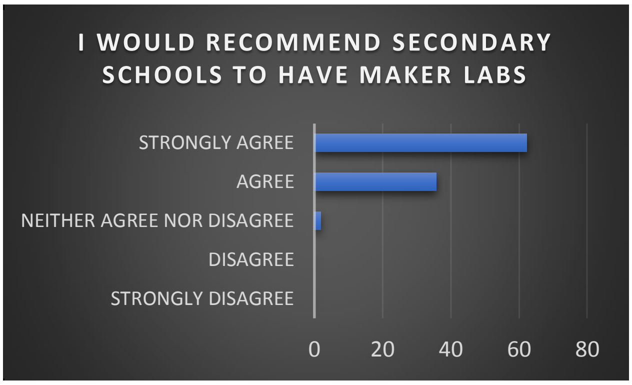

FIGURE XIX. *Teachers' questionnaire item 13 results*

4.5. STEM PUPILS' GENERAL AWARENESS ON THE CONCEPT OF INTEGRATING MAKERSPACES IN SECONDARY SCHOOLS

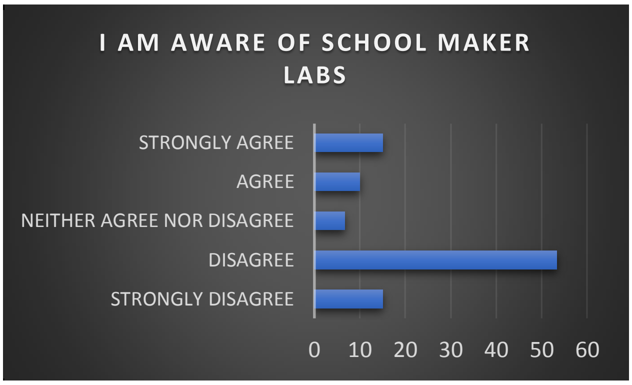

FIGURE XX. *Pupils' questionnaire item 1 results*

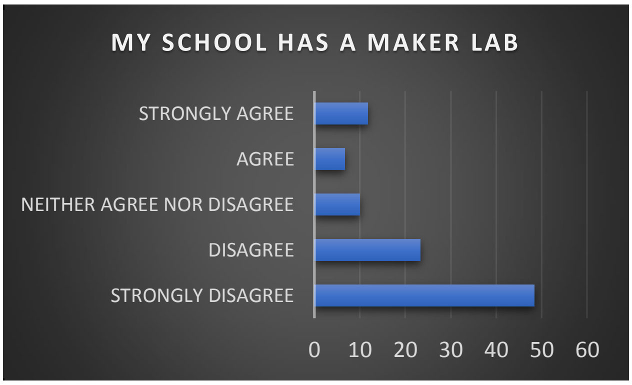

FIGURE XXI. *Pupils' questionnaire item 2 results*

4.6. STEM PUPILS' GENERAL EXPERIENCE WITH MAKING STEM RELATED PRODUCTS

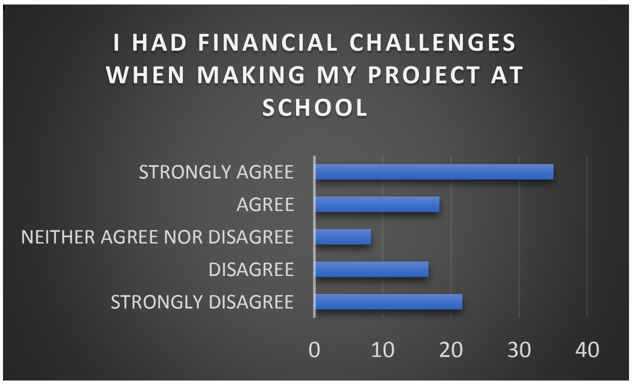

FIGURE XXII. *Pupils' questionnaire item 3 results*

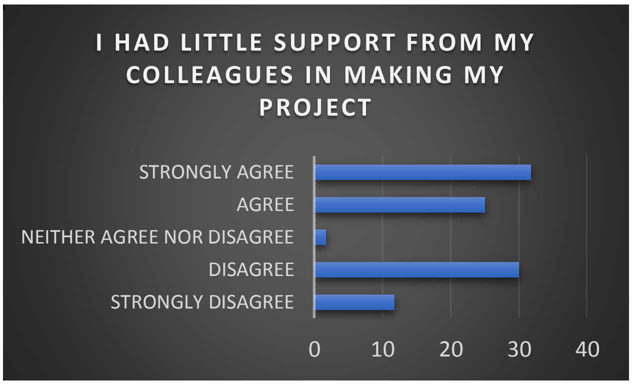

FIGURE XXII1. *Pupils' questionnaire item 4 results*

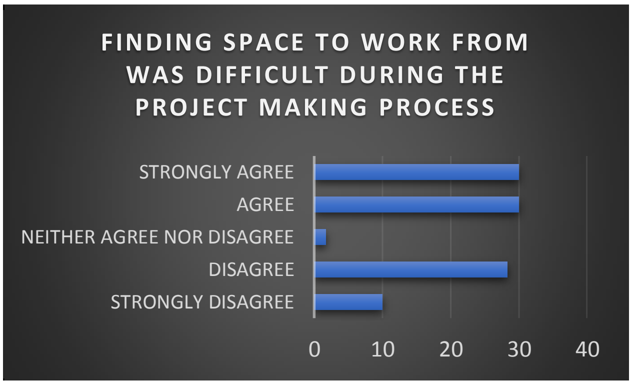

FIGURE XXIV. *Pupils' questionnaire item 5 results*

FIGURE XXV. *Pupils' questionnaire item 6 results*

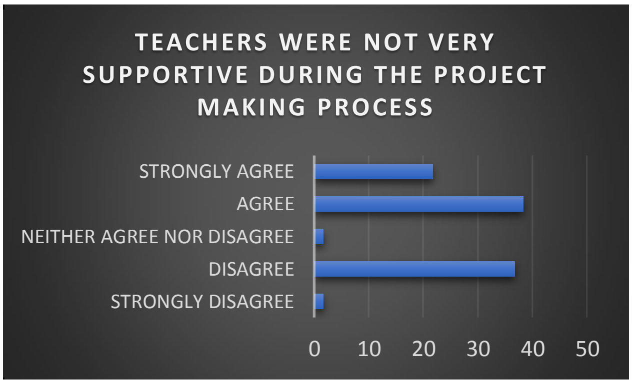

FIGURE XXVI. *Pupils' questionnaire item 7 results*

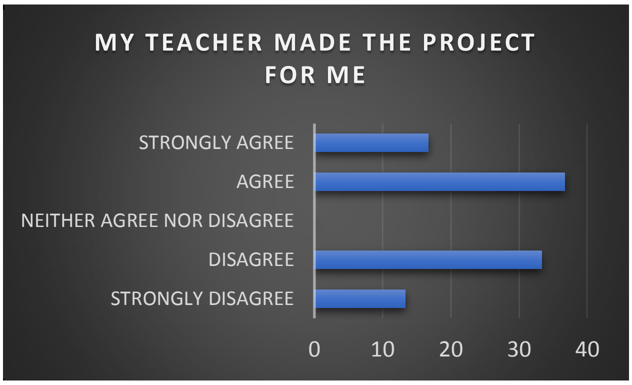

FIGURE XXVI1. *Pupils' questionnaire item 8 results*

FIGURE XXV1II. *Pupils' questionnaire item 9 results*

FIGURE XXIX. *Pupils' questionnaire item 10 results*

4.7. STEM PUPILS' PERCEPTION OF THE BENEFITS OF MAKERSPACES

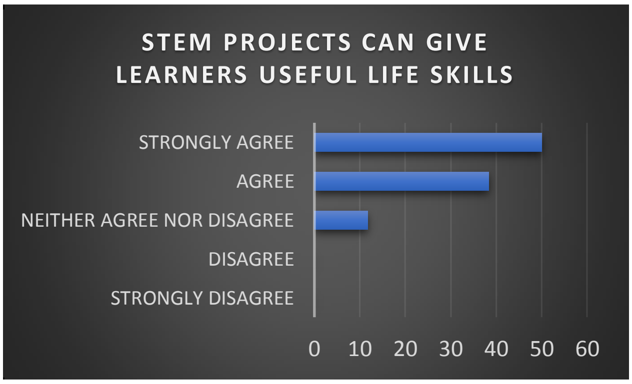

FIGURE XXX. *Pupils' questionnaire item 11 results*

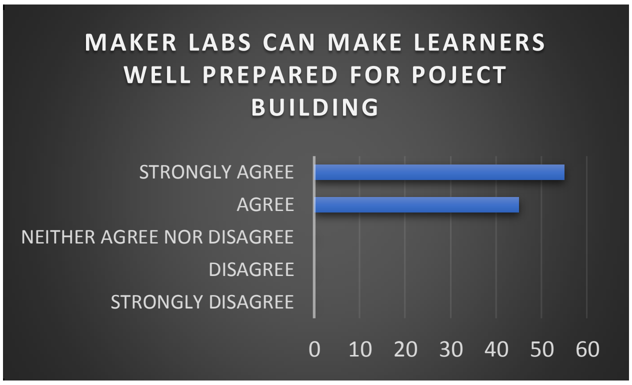

FIGURE XXXI. *Pupils' questionnaire item 12 results*

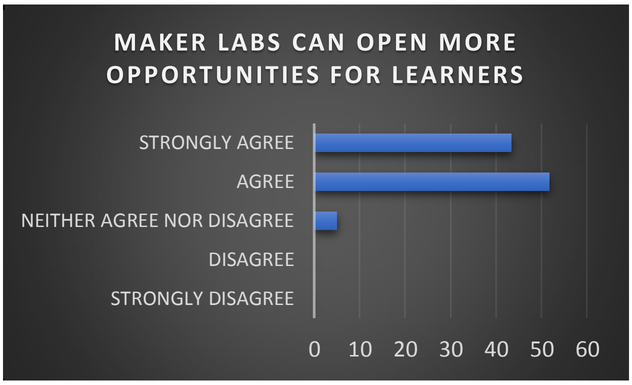

FIGURE XXXII. *Pupils' questionnaire item 13 results*

4.8. STEM PUPILS' RECOMMENDATION ON THE INTEGRATION OF MAKERSPACES IN SECONDARY SCHOOLS

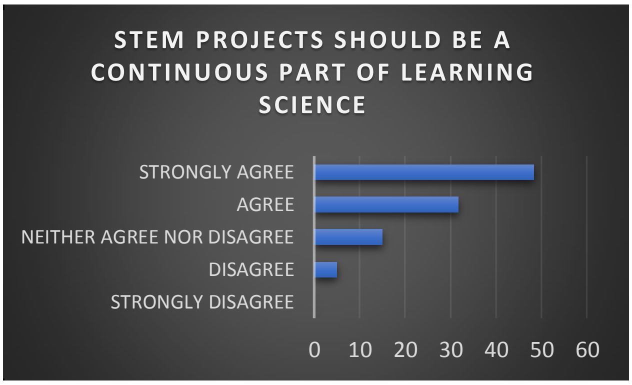

FIGURE XXX1II. *Pupils' questionnaire item 11 results*

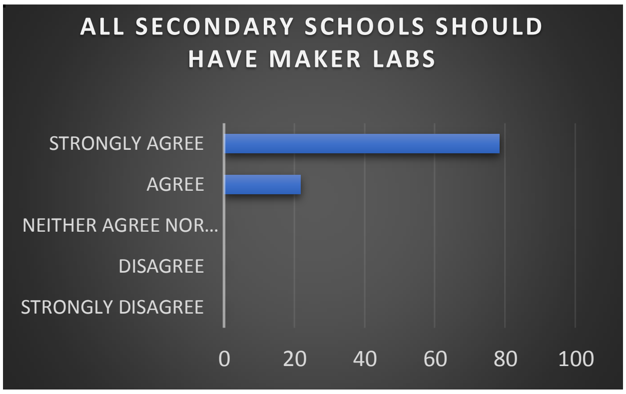

FIGURE XXXIV. *Pupils' questionnaire item 11 results*

4.9. STEM PUPILS' COMMENTS ON THE MAKERSPACE CONCEPT

In the open-ended section of the pupil's questionnaire, STEM pupils were given chance to comment on the concept of integrating makerspaces in secondary schools. The intention was to reveal learners' perception of the concept of makerspaces with some open justification of their perception. All the comments by the STEM pupils revealed that they really need makerspaces in their secondary schools. 96% of the pupils justified their positive perception about the makerspace concept, with 67% directly relating makerspaces to acquisition of skills and 29% relating makerspaces to intellectual development. Some of the typical comments by those who related makerspaces to acquisition of skills were as follows: 'it (makerspace) would be very helpful as it would enable learners to acquire the skills that they need in society'; 'a maker lab is very nice idea that should be implemented not only in secondary schools but also primary and early childhood to help them acquire skills at a very young age'; 'I strongly feel maker labs should be a part of learning science in order to see learners useful skills'; 'it (maker lab) is a very good way of improving learners' ability to invent and discover more in science'; 'I really think it would help young people and their bright minds to make new and helpful innovations'; 'maker labs should be available in each and every school because they would help in the development of new young scientists and many more skills'; 'maker labs should be available in every school because they will help to train the upcoming engineers, scientists and technicians at an early age'. One comment even revealed that makerspaces can promote soft skills like communication and teamwork. Typical comments showing a link between makerspaces and learners' intellectual development included the following: 'the school maker lab can help improve the performance of the learners in STEM subjects across the country'; 'they (maker labs) should be in all schools because they will make pupils to develop their thinking'; 'very important learners ready to expand intellectually'; 'it will help learners understand certain concepts and gain more knowledge'; 'the maker lab concept is a very good idea in that it will make learners think outside the box'; 'it's a good concept because it will also broaden learners' minds'. Two of the comments from 4% who never justified their perceptions were: 'they (maker labs) should be made in secondary schools as soon as possible'; 'it (maker lab) is a very appropriate concept that should be a priority for all schools in Zambia'.

5.0. DISCUSSION OF FINDINGS

5.1. STEM TEACHERS' GENERAL AWARENESS ON THE CONCEPT OF INTEGRATING MAKERSPACES IN SECONDARY SCHOOLS- responses of STEM teachers revealed that 41.5% were not aware of school makerspaces, 45.2% expressed awareness and 13.2% couldn't tell whether they were aware or not. The percentage of STEM teachers who expressed awareness was larger than expected. This result was not expected as no literature mentioned the concept of makerspaces in any poor African countries and only one secondary school was found to experiment with the integration of a makerspace on the Copperbelt province of Zambia.

5.2. STEM TEACHERS' GENERAL EXPERIENCE WITH MAKING PRODUCTS IN THEIR STEM SUBJECTS- 90.5% of STEM teachers agreed that their subject specialisation involves making products and only 9.5% were not in a position to tell whether their subject specialisation involves making products or not. None of the STEM teachers thought that their subjects had nothing to do with making products. This is in line with literature which asserts that STEM subjects cannot be separated from innovation which is based on the process of making products (Ismail, 2018). However, 15.1% of STEM teachers confirmed that they had no practical experience with making products in their subject specialisation and 22.6% were not sure about their practical experience. This left only 62.3% of STEM teachers confirming having practical experience with making products. This result is similar with Olamide's assertion that most STEM teachers in Africa are not trained to understand STEM or qualified to teach STEM as they do not even know the right technology and engineering skills used in most industries (Olamide, 2022). Interestingly, 96.3% of STEM teachers surveyed expressed interest in making science products.

5.3. STEM TEACHERS' PERCEPTION OF THE BENEFITS OF MAKERSPACES ON LEARNERS- STEM TEACHERS' responses revealed that they perceive STEM makerspaces to be highly beneficial to the learners. Almost all the STEM teachers in the study either strongly agreed or simply agreed that STEM makerspaces can provide learners with the opportunity to innovate, create real-world applications for classroom concepts, lead learners to make failure into a learning experience, expose learners to new opportunities, build critical thinking and problem-solving skills, popularise STEM in secondary schools and boost learners interest and confidence in STEM. Very few STEM teachers expressed uncertainty as to whether makerspaces are beneficial or not and less than 10% suggested that makerspaces cannot lead learners to learn how to make failure into a learning experience. This result is in line literature as STEM makerspaces are known to foster innovation through hands-on experimentation, allow learners to move from an abstract concept to a real-world understanding, allow learners learn how to make failure into a learning experience, provide learners with the opportunity to learn something new and promote a wide range of 21st century skills in learners (Bevan, Petrich, & Wilkinson, 2014; Hsu, Baldwin, & Ching, 2017).

5.4. STEM TEACHERS' RECOMMENDATION ON THE INTEGRATION OF MAKERSPACES IN SECONDARY SCHOOLS- an overwhelming 98.1% of STEM teachers recommended that all secondary schools should integrate makerspaces. More than 60% of these STEM teachers recommended secondary schools to have makerspaces. Following the fact that these teachers perceived makerspaces to be beneficial, it no surprise that they recommended their integration in secondary schools. This was expected as literature shows that makerspaces have gained traction in schools of most developed countries (Dougherty, 2016).

5.5. STEM PUPILS' GENERAL AWARENESS ON THE CONCEPT OF INTEGRATING MAKERSPACES IN SECONDARY SCHOOLS- close to 70% of STEM pupils surveyed were not aware of school makerspaces. In fact, about 72% of STEM pupils confirmed not having makerspaces at their schools. Very few pupils expressed awareness about makerspaces and most likely they were pupils from Chiwala Provincial STEM Secondary School or those from nearby schools. This lack of knowledge about makerspaces was expected as no literature showed awareness of the concept of makerspaces in poor African countries.

5.6. STEM PUPILS' GENERAL EXPERIENCE WITH MAKING STEM RELATED PRODUCTS- questionnaire items concerning the general experience of STEM pupils with making of things were focussed on the projects they had made for their JETS fair competition. It was hoped that the information given by the pupils would shed light on their experiences with making STEM related products. For instance, 53% of STEM pupils expressed having financial challenges during the process of making their product and 57% confirmed receiving very little technical support from their colleagues. 60% of STEM pupils had difficulties finding convenient space to work from during the product making process and 67% confirmed that they just started working on the project when they were informed about JETS fair competition. On one questionnaire item, 60% of pupils expressed that teachers were not very supportive during the product making process and yet on another questionnaire item 53% revealed that their teachers made the projects for them. The other two questionnaire items revealed that 33% of the pupils received their projects from their guardians and 25% received help from their guardians during the process of making. These results are consistent with what is expected from learners who have no experience of makerspaces (EU, 2018).

5.7. STEM PUPILS' PERCEPTION OF THE BENEFITS OF MAKERSPACES- STEM pupils' perception of the benefits of makerspaces was positive. 88% of STEM pupils agreed that making STEM products can give them useful life skills and all the pupils thought makerspaces can make them well prepared for project building. Furthermore, 95% felt that makerspaces can open more opportunities for learners. The results confirm the characteristics of the maker movement, one of which is promoting invention and innovation (useful life skills) as stated by González González & Arias (2018).

5.8. STEM PUPILS' RECOMMENDATION ON THE INTEGRATION OF MAKERSPACES IN SECONDARY SCHOOLS- 80% of STEM pupils expressed the need for STEM product making to be a continuous part of learning STEM related subjects and all the pupils recommended the integration of makerspaces in secondary schools. This trend was also observed in the general comments made by the pupils in the open-ended section of the questionnaire. All the comments revealed positive interest of learners in the concept of the makerspace in schools for technical and soft skills development. This is cardinal as research has shown that the development of the two sets of skills leads to holistic learning (Phiri, & Jumbe, 2019). Some even expressed the need for the introduction of makerspaces in schools as soon as possible. Such recommendation is similar to the excitement of learners exposed to STEM maker labs in developed countries (Dougherty, 2016).

6.0. CONCLUSION/RECOMMENDATION

The study had four objectives, namely:

i. To determine STEM Teachers' and Pupils' general awareness on the concept of integrating makerspaces in secondary schools.
ii. To determine STEM Teachers' and Pupils' general experience with making STEM-related products.
iii. To determine STEM Teachers' and Pupils' perception on the benefits of makerspaces on STEM learners.
iv. To determine STEM Teachers' and Pupils' recommendation on the integration of makerspaces in secondary schools.

Results have revealed that the general awareness of both STEM teachers and pupils on the concept of integrating makerspaces in schools is generally poor. However, it must be noticed that the teachers' general awareness was far much better than that of pupils. Even though an excellent percentage of STEM teachers acknowledged that their STEM specialisations involved making products, a reasonable number felt they don't have enough practical experience with making STEM related products. STEM pupils also acknowledged that they are highly limited when it comes to their experience with making STEM related products. The only time they get engaged in making is during the JETS fair competition period. Making is not taken as a learning process but simply for competition. This is why some learners confirmed that their JETS projects were made either by teachers or guardians. Some learners even revealed an item which was not included in their questionnaire- that most projects were not original innovations by learners but simply copied directly from the websites that offer science projects. Both STEM teachers and pupils perceived the integration of makerspaces in schools to have positive results on the development of learners' invention and innovation skills. Almost all the teachers and learners either strongly agreed or simply agreed that STEM makerspaces can provide learners with the opportunity to innovate, create real-world applications for classroom concepts, lead learners to make failure into a learning experience, expose learners to new opportunities, build critical thinking and problem-solving skills, popularise STEM in secondary schools and boost learners interest and confidence in STEM. The results also revealed that all STEM teachers and pupils recommended the integration of makerspaces in schools. In line with this conclusion, the following recommendations are made in this study:

I. The government to consider spicing up STEM education with the integration of makerspaces probably with emphasis on current international trends such as Electronics and Coding skills related to ARDUINO, like the initiative taken by Kenya.
II. Universities and Colleges offering teacher training to emphasise maker skills for all STEM

teachers, coding and practical electronics for Design and Technology, ICT and Physics teachers.

III. Schools to have maker skills department with constant interaction between learners and external experts in different fields.

IV. School administrators to be supportive of STEM teachers' and pupils' active involvement in makerspaces.

V. Educational researchers to carry out more research on the actual experimentation of makerspaces in STEM education in Zambian schools.

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Author Profile

Moses Kayola Phiri received his Master of Science in Physics Education from The Copperbelt University in 2019. He currently works for the Zambian Ministry of Education as a Physics Teacher.

Vincent Chinyama received his Master of Science in Physics Education from The Copperbelt University in 2019. He currently works for the Zambian Ministry of Education as a Physics Teacher.

Lex Rourke has a Dip. Electronics Engineering (RSA) and Dip. M. Training Management (RSA). Currently works as CEO of STEMTronics-Consultancy specialising in STEM education in schools as well as Innovation Management in the fields of Appropriate Technology, Renewable Energy and Climate Science.

Jack Jumbe is currently working as a Senior Lecturer at The Copperbelt University.