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STEM Principles in Action: Exploring the Relevance of the Physics Curriculum in Artisan Productions in the Hatfield-Mbare District, Zimbabwe

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Abstract: This case study investigated the application of physics principles in artisan productions in the Hatfield- Mbare District in Harare, Zimbabwe. Through a qualitative research approach, 65 artisans were purposively sampled from the Mbare- Magaba Siyaso informal industrial hub to explore their experiences and applications of physics principles. The findings revealed a diverse range of projects and products that showcase the relevance of physics in these industries, despite artisans having limited formal physics education. The study highlights the importance of contextualizing physics education, recognizing informal learning, and building on existing knowledge to enhance students' understanding and interest in physics. Under Zimbabwe's Education 5.0 framework and new heritage-based curriculum, this study underscores the potential for physics education to drive innovations, entrepreneurship (techno-preneurship) and industrialization. Real-world applications of physics were highlighted to inspire students, teachers and policy-makers to promote physics education, increase enrollments in both physics classes and teacher training programs and to foster a culture of technology innovation and problem solving. This study's insights can inform strategies to make physics education more engaging, relevant and accessible, ultimately contributing to Zimbabwe's economic growth and development.

Keywords: *Physics Education; STEM Principles; Artisan Productions; Education 5.0; Informal Sector; Real-World Applications; Action; Relevance.*

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I. INTRODUCTION

The informal sector in Zimbabwe, particularly in areas like Mbare-Magaba Siya-So hub, has witnessed rapid growth, with many individuals turning to self-employment and entrepreneurship (Ndlovu, 2024; and, Sheikh, 2019). This sector is characterized by individual or family self-employment effort in unregistered, microbusinesses, small-scale industries operating in undesignated open-spaces, street corners and from home backyards shacks (Tarupiwa, 2020; and, Masanja, 2012). Economic activities in this sector take place outside the formal norms of economic transactions established by the state or formal business practices, but are not in themselves illegal (Uzhenyu, 2015). This sector may generally be referred to as artisan productions since the operators work skillfully with their hands or on hand-tools to produce products with a unique or distinct value (Pret & Cogan, 2019).

In education, STEM is an acronym for the interdisciplinary approach to teaching and learning that involves integrating science, technology, engineering, and mathematics (Hallinen, 2025). In Zimbabwe, science disciplines are taught at lower levels as either environmental, core, general, integrated, extended, combined, biological or physical sciences; but, become traditionally specialist STEM subjects such as biology, chemistry, computer science, geography, mathematics and physics at higher levels (Dube, 2018; Mberi & Phambili, 2018). Artisan industries in the Mbare-Magaba Siyaso hub, despite their informal nature, are producing quality goods and services that are addressing societal needs (Manyati, Kalima, Owolabi & Mutsau, 2024; and, King, 1977), often leveraging STEM principles.

While products, models and prototypes produced link to scientific ideas embedded in each of the STEM subjects (Manyati & Mutsau, 2019), this paper explored the relevance of only one, namely, the physics curriculum. In this study STEM in action, refers to the phenomenon when physics principles taught in class are now finding applications in society.

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A paradox exists in that, the current physics education in formal schools in Zimbabwe is facing significant challenges (Macleod, 2013), including a dire shortage of qualified teachers and poor teaching (McDermott, 1998), low student enrollment (Alsop & Watts, 2000), high dropout rates particularly girls (Zohar, 2005), and poor performance in physics examinations compared to other STEM disciplines. The huge number of failing or dropping out students find themselves unemployed and creating physics-related self-help jobs/ projects in artisan-like trades in informal sector. There is a clear disconnect between disparities in physics enrolments and uptake versus the sudden up surge in physics-related artisan productions. Educationists and researchers cannot ignore this phenomenon, but focus into closing the gap between theory and practice (Arteaga, Biesbroek, Nalau, & Howes, 2024)

➢ *Purpose of the Study*

The study seeks relevancy (Kudakwashe, 2021), utility and importance of physics and, thereby, stimulate interest and enrollment in the subject at all levels of the education system.

➢ *Research Objectives*

- To describe the types of projects and products that demonstrate the relevance of physics in artisan productions
- To investigate the background and physics education experiences of artisans in relation to their application of physics principles
- To explore the application of physics principles in artisan productions in the Mbare-Magaba Siyaso hub.

➢ *Research Questions*

- What types of projects or products showcase the relevance of physics in artisan productions, and what physics concepts are embedded in them?
- How do artisans' backgrounds and physics education experiences influence their application of physics principles in their work?
- What physics principles are used in artisan productions in the Mbare-Magaba Siyaso hub, and how are they applied?

➢ *Significance of the Study*

This follow-up study of school graduates and drop-outs from aims to evaluate the effectiveness of the physics curriculum by tracing artisans' educational backgrounds and experiences in this production sector. By examining where, when, and how they acquired utility physics concepts relevant to their projects, the study not only affirms areas of meriting reinforcement leading to excellency, but also identifies potential gaps and areas of weakness needing improvement. The findings will inform schools, students and teachers about physics 's practical applications in society, self-help/employment projects for themselves and others, thereby promoting a broader understanding of its value and encouraging more students to pursue physics and related careers.

II. LITERATURE REVIEW

The informal sector plays a significant role in many economies, particularly in developing countries (Ndlovu, 2024; Zaki, 2017, and, Mohammed, 2024). Artisans in this sector often apply scientific and technological knowledge, including physics, in innovative ways (Kalyani, 2024). However, research suggests that many artisans lack formal education in physics, relying on experiential learning and informal knowledge sharing (Manyati & Mutsau, 2019, and Garrick, 1998).

Studies have shown that physics education can be made more relevant and engaging by incorporating real-world applications and examples (Bao & Koenig, 2019; Hake, 1998, and Redish, 2003). Physics as one of the most essential STEM subjects needed to develop robust STEM industries nationwide. Physics-related technological and engineering innovations are needed as the world becomes increasingly industrialized, mechanized, digitized, more energy conscious and overwhelmed by need for transport systems, ICTs and telecommunications. The artisan productions (informal) sector in Zimbabwe has become a dominant force in the face of a struggling economy and dwindling established industry. Research into this area is on-going.

Secondary, college and university graduates often do not receive relevant physics and practical education or training by the tie they drop-out into the informal sector offering a national set-back. This study aims to contribute to the existing literature by exploring the application of physics principles in artisan productions, with a focus on the Mbare-Magaba Siyaso hub in Zimbabwe. Furthermore, recognizing and valuing informal learning pathways can help artisans access further education and training opportunities (Livingstone, 2001; and Brookfield, 1981).

III. METHODOLOGY

This study employed a qualitative research approach (Denzin, 2017) with a case study design to gather in-depth rich data (Yin, 2018) by focusing on the application of physics principles in-situ artisan productions at Mbare-Magaba Siyaso informal industrial hub in Harare, Zimbabwe. By concentrating on phenomena in this particular hub, the study aimed to provide a detailed understanding of the complex interactions between physics principles and artisan productions within this unique context

➢ *Sampling*

Given the numerous artisan production projects within the Mbare-Magaba Siyaso hub, a purposive sampling approach (Ames, Glenton, & Lewin, 2019) targeting 65 selected sites that showcased a diverse range of projects and products was employed. Artisan production sites were selected on their willingness to participate ensuring a collaborative and informative data collection process This approach enabled the researcher to capture a broad spectrum of experiences and applications of physics principles.

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➢ *Data Collection Procedures*

Data collection involved a combination of:

- *Observations and Artefact Collection:*

Photographs and detailed notes on project types, products and physical processes were taken or recorded at each artisan production site visited. Relevant products such as models and prototypes that demonstrated to be direct application of physics principles were collected as artefacts;

- *Interviews:*

In-depth interviews were conducted with artisan participants to gather information on their backgrounds, physics education experiences, and the physics principles they individually applied in their work. The interviews also gauged practicing artisans' knowledge and understanding of physics concepts embedded in their projects and products.

➢ *Data Analysis*

A thematic analysis approach as described by (Braun & Clarke, 2006) was used to identify patterns and themes in the data related to the application of physics principles in artisans' experiences. This approach enabled the researcher to uncover rich insights into the different ways artisans apply physics principles in their work and how these principles contribute to their products and projects.

IV. PRESENTATION OF RESULTS

In order to make the findings more accessible, clearer and concise, this section presented the results using the research questions (RQs) as headings (Bingham, 2023). This strategy was useful by ensuring that the research questions have been answered and enables readers to quickly ascertain where answers to the research questions are.

➢ *Findings for RQ1. What Types of Projects or Products Showcase the Relevance of Physics in Artisan Productions, and what Physics Concepts are Embedded in them?*

- *Theme: Physics in Artisan Productions: STEM (Physics) in Action*

The research revealed a diverse range of projects and products that showcase the relevance of physics in artisan productions. The study identified 19 categories of physics - related trades, demonstrating the length and breadth of physics applications in these types of industries in this sector. artisans displayed satisfactory knowledge of physics concepts pertaining to their projects, often beyond their formal education levels. However, misconceptions were also present, highlighting the need for further education and training. Table 1 below shows the type or kind of projects that showcased the relevance of physics.

Table 1 Types of Physics-Related Projects/Trades (N= 65)

	Project Type	**frequency**
1	Motor rewinding & lawn mowers	3
2	Loudspeaker rewinding & manufacture	7
3	Cell phone/Repairs	5
4	Radio/TV repairs	2
5	Computer Repairs	3
6	Electrical Installation & Repairs	4
7	Solar technologies & installation	2
8	Refrigeration & Compressors	3
9	Tyro & Tube servicing	4
10	Filming & Photography (audio -video)	3
11	Sound engineering and recording	2
12	Weighing (people & metals)	3
13	Watch repairs	2
14	Bicycle repairs	3
15	Auto- electrics	3
16	Motor mechanics (engineering)	4
17	Batteries & battery charging	6
18	Welding & Brazing	3
19	Scotch carts & wheelbarrow manufacture	5

The artisans' practical skills were impressive, with many demonstrating expertise in manual skills such as connecting, assembling, soldering, brazing and welding. These skills were claimed to have been acquired through hands-on experience and informal learning channels, including family members, friends, and community of practice groups. Indigenous knowledge systems (IKS)also played a significant role in shaping their understanding of physics concepts

Interestingly. Artisans did not necessarily recognize or label their work as "physics -related" but rather as "science-related". They were drawn to physics concepts that were easy to apply, with a utility value and resulted products, goods or services in high-demand by customers. Many artisans professed to have learned physics concepts through general science, integrated science, core science, extended-science and combined science syllabi, rather than from studying physics as a standalone subject. The following pie charts (Figures 1 (a), (b), (c) and (d), below) indicate how the

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artisans rated the usefulness of physics in their projects compared to the other science subjects

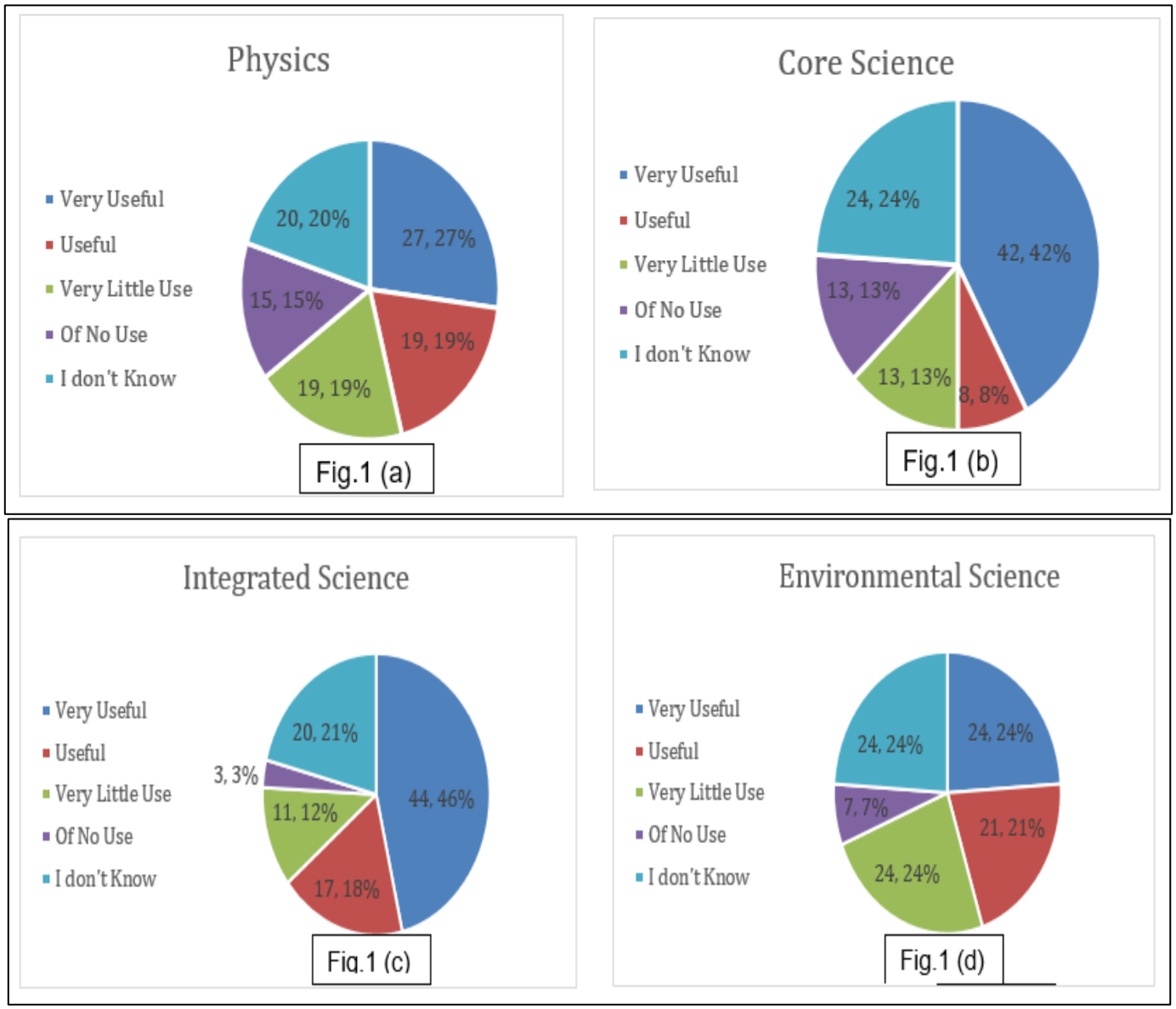

Fig 1 Rating of Usefulness of Subjects in Artisan Projects

The study also revealed that artisans displayed inventiveness and innovation skills, designing, modifying and improvising models and prototypes to meet customer needs. Overall, the findings highlight the importance of physics in artisan productions and the need for further education and training to enhance artisan's understanding and application of physics concepts

➢ *Findings for RQ2. How do Artisans' Backgrounds and Physics Education Experiences Influence their Application of Physics Principles in their Work?*

- *Theme: Artisans Backgrounds and Physics Education Experiences*

The study revealed that artisans' backgrounds and physics education experiences significantly influenced their applications of physics principles in their work or projects. Most artisans had a basic education background, typically up to "O" Level, with a high literacy rate, but few had pursued physics education beyond this level. Notably, no university physics graduates were found among the artisans, citing financial constraints, family obligations, and lack of relevant qualifications as barriers to further education. Figure 1 summarizes the highest educational levels of the artisan participants.

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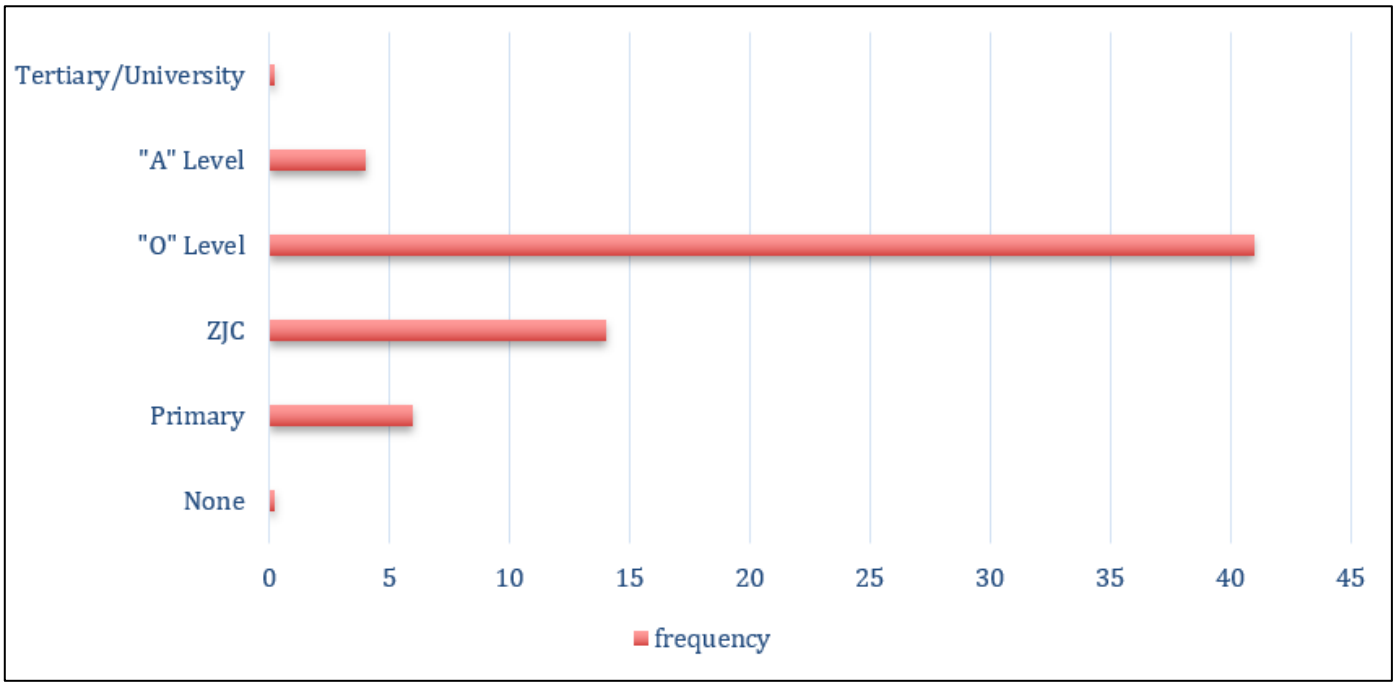

Fig 2 Highest Education Levels of Artisans

Gender disparities were evident, with limited participation of girls in technology projects and an absence of women in heavy duty machinery and masculine jobs. Many artisans migrated from rural and or farming areas, smaller towns to big cities, often driven by hardships that led them to start their own self-help ventures or get employed by others in similar projects. Figure 2, below shows rural to urban migration statuses of the artisans now working in the Mbare-magaba Siyaso hub as per study sample.

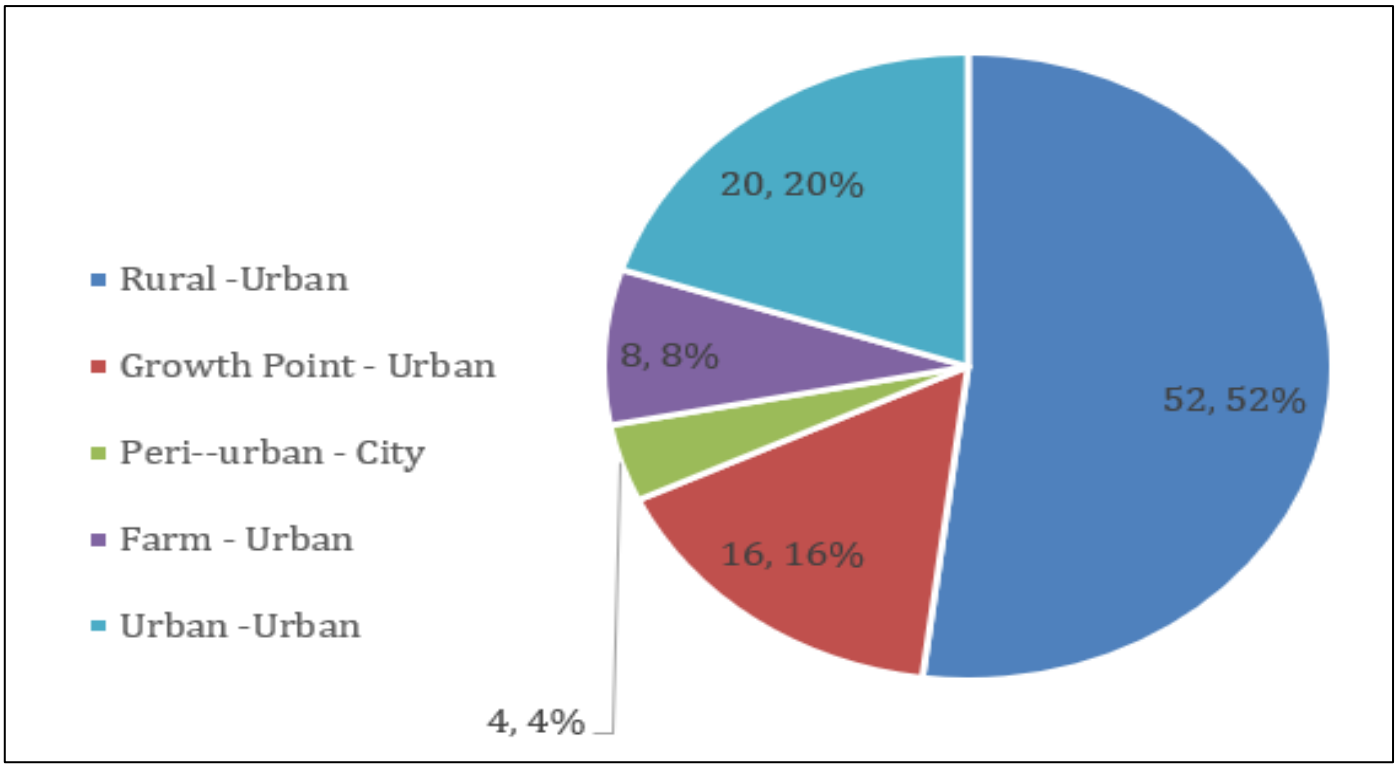

Fig 3 Internal Migration Statuses of Artisans

Despite having poor physics education backgrounds, artisans demonstrated expert-level skills and produced goods and products that matched or were competent enough for local markets. This highlights a mismatch between their formal education and expertise they have developed through hands-on experience and vocational training

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The role of vocational and technical colleges, polytechnics and communities of practice was seen as crucial for acquiring higher skills and knowledge in specific trades. These institutions provided artisans with the necessary training and support to develop skills and adapt to changing demands in their industries.

➢ *Findings for RQ3. What Physics Principles are Used in Artisan Productions in the Mbare-Magaba Siyaso hub, and How are They Applied?*

- *Theme: Physics Principles in Artisan Productions: Relevance of the Physics Curriculum*

The study identified a range of physics principles used in artisan productions at the Mbare-Magaba Siyaso hub. Through a document analysis of current curriculum materials and drawing on the researcher's own experiences teaching physics specific concepts and principles of physics applied in various projects were able to be pinpointed. Table 2 (a) and (b), below, illustrate how observed physics concepts/ principles in action relate to project (business) names or applications and their tie to relevant skills needed where they operate.

Table 2(a) The Relevance of Mechanics, Fluid Dynamics and Thermodynamics to Projects

Physics Concept/Principle	Project Name/ type	Deals with	Skills
Mechanics, Machines, Force & Motion	One Start Engine Over haulers	Auto-mechanics	Engine diagnostics, replace components, overhaul engines, servicing, maintenance
Machines	Jena Cycle Repairs	Bicycle repairs	Brakes, gears, tyre repair, wheel truing & balancing, chain maintenance
Gas pressure and pneumatics	SaMutoko Tyre Services	Tyre and tube repairs	Tyre/tube diagnosis, patching punctures, mounting and balancing
Structures: levers and beams	Tawana Skotch Kart	Making Scotch Carts wheelbarrows	Levers, wheels, tyre, metal fabrication, welding
Hydraulics	Mono Pumps	Pumps, water pumps, overhead irrigation	Gauge calibration, welding, joining, mounting
Thermodynamics Heat Heat Transfer Convection Conduction Radiation	Majerimani Pots & Pans	Pot making	Designing Shaping, metal fabrication Molding, Filing, Welding, painting,
	Coke Ovens	Coke & Coal Oven making	
	Dhuvura welders	Welding & Metal fabrication	
	Cool it	Electric fans & air con	Diagnosis, compressors, evaporators, charging refrigerants, insulation and cabinet repairs
	South & North Pole Refrigerators	Refrigeration	

In mechanics, artisans applied concepts such as force, motion and energy in projects involving machinery, tools and equipment. Motor vehicles need servicing on a daily basis while devices such as scotch carts (ngoro), wheelbarrows (bhara) and water pumps are important in Zimbabwe's agricultural and construction sector. The principle of thermodynamics which deals with heat transfer and energy conversion was applied in refrigeration and metalworking and welding and demanded that artisans design, optimize tools or equipment to create innovative products, troubleshoot, fix or repair and bring solutions to problems.

Table 2 (b) The Relevance of Waves and Sound, Optics, Electricity and Magnetism to Artisan Projects

Physics Concept/Principle	Project Name/ type	Deals with	Skills
Waves & Sound	Max's Super-Sounds	PA Systems & loudspeakers	Winding coils; assembling magnetic components. Soldering electrical connections; building speaker cabinets; testing
Light and Optics	Sharp Photos Nashe Films & Videos	Photography & Filming	Camera settings, focusing, lighting, film processing. Editing software, camera maintenance
Reflection & Refraction	Dhliwayo Glasses	Mirrors and windows	Setting, putty, glass cutting, measurements
Electromagnetic waves & electronics	Remote Electronics	Mobile phones & Telecommunications	Charging ports, battery servicing, screen replacements, trouble shooting
Electricity	Goodie's Electrics	Electrical installations and repairs	Electrical circuitry, wiring measuring voltage and current
Electrochemistry	Vela's Battery Charge	Battery charging	

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Electromagnetism	Mupositori Generators & Motors	Generators and motors rewinding	Connecting electrical circuits, battery maintenances winding coils, core-iron, insulation, testing and trouble shooting diagnosis and repair, soldering, de-soldering, tuning, trouble shooting
Analogue & Digital Electronics	Lovemore's Radio & TV repairs	Radio and TV repairs	

Physics was in action in the use of gadgetry like cameras, speakers, microphones and cellular phones. The installation of car rear view mirrors used the laws of reflection but skills was needed in glass cutting and fitting. In electromagnetism, artisans used concepts related to electricity and magnetism in projects involving electric circuits, generation of electricity by batteries or generators, and electronics circuits.

There are numerous projects that could have been used in the study, but these seemed sufficient from which important lessons can be drawn from, By examining the specific physics principles used in artisan productions, a deeper understanding of the critical role that physics plays in these industries and the innovative ways artisans in this sector apply scientific concepts create practical solutions

V. CONCLUSION

This study has provided valuable insights into the role of physics education in artisan productions at the Mbare - Magaba Siyaso hub. The research revealed a diverse range of projects and products that showcase the relevance of physics in these industries, despite artisans having limited formal physics education. The findings highlight the importance of practical hands-on skills, innovation, and problem-solving in artisan work, as well as potential for vocational training and technical education to support artisans' development

In the context of Zimbabwe's Education 5.0 framework, which emphasizes innovation, entrepreneurship, and industrialization (MHTESTD, 2016; and. MoESP, n.d.), this study underscores the need for a strengthened STEM education prepares students for the demands of small homebased industry, informal sector industry formal sector industry and international industry. The new heritage-based curriculum. Which seeks to integrate indigenous knowledge systems (IKS) with modern western scientific knowledge, offers opportunities for promoting contextualized learning and innovation in physics education., By leveraging these initiatives, Zimbabwe can foster a culture of innovation and entrepreneurship driving industrialization and economic growth. The study's findings have significant implications for our understanding of the intersection of physics education and industry and can inform strategies to support artisans' innovations and while at the same time promoting students' interest in the subject and catalyze enrolment in the subject.

IMPLICATIONS

This study has far-reaching implications for physics education, vocational training and industry development physics education. Key considerations include:

- *Contextualizing Physics Education:*
  Adopting an inclusive approach integrating real-world applications, traditional knowledge systems and ethno-physics can make physics more engaging, relevant and exciting. For instance, incorporating indigenous concepts like Ubuntu, traditional stories, legends, cultural tools, instruments and tools, games and superstitious beliefs can help illustrate complex physics principles.

- *Recognizing Informal Learning:*
  Valuing informal learning pathways such as traditional apprenticeships and community-based training can provide artisans with recognition and access further education and training. This acknowledges the importance of Indigenous Knowledge Systems (IKS) and cultural heritage in shaping understanding and practices.

- *Building on Existing Knowledge:*
  Educators can build on artisans' existing knowledge and experiences, addressing misconceptions and enhancing their understanding of physics concepts. By doing so, we can create a more inclusive and effective learning environment that honors diverse knowledge systems.

- *Improving Access to Quality Education:*
  Efforts should be made to improve access to quality education, particularly for girls and those from disadvantaged backgrounds especially at lower levels where they drop-out.

- *Strengthening Vocational Training:*
  Vocational and technical training programs should be strengthened to equip artisans with higher skills.

- *Supporting the Informal Sector:*
  Providing support, such as training, mentorship, funding and equipping with tools and resources, can help informal sector entrepreneurs establish industries that thrive.

- *Heritage-Based Hands-on Topics:*
  Incorporating more heritage-based, hands-on, and utility-focused topics can enhance physics education.

- *Industrial and Project-Related Topics:*
  Including more industrial and project-related topics can make physics education more relevant and adventurous.

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- *Industry Linkages and Modernizing Innovations:*

Establishing links with relevant industries, technologies, and international projects can modernize innovations in physics education.

RECOMMENDATIONS

The findings of this study can inform policy and program development, enhancing the relevance of physics education, drawing interest among students, increasing enrollment in physics classes and teacher education, and supporting growth in the informal sector that leads to innovation and industrialization. The study recommends:

- *Promotion of STEM Education*, particularly physics, to equip students with a solid foundation for technology and technological innovations. This can be achieved by:
- *Integrating practical applications*: Reviewing physics curricula to produce practical applications and real-world examples that resonate with artisans' experiences
- *Strengthening vocational training programs* to equip artisans with higher skills, enhancing their employability and entrepreneurial capabilities.
- *Fostering and building partnerships* between
- *Formal Education Institutions*: Collaborating with schools, colleges and universities to develop curricula that meet industry needs.
- *Polytechnics, technical colleges and Community of practice centers*: providing artisans with access to vocational skills training and certification.
- *Engaging with industries and informal sector* entrepreneurs to identify skills gaps and develop targeted training programs, internships and work-related learning.
- *Developing curricula* that incorporate industry needs and applications, ensuring physics is education is relevant and applicable.
- *Provide ongoing teacher training and support for physics teachers* to stay updated on industry developments and applications.
- Supporting the growth of the informal sector through targeted training, attachments, internships mentorship, and resources, promoting entrepreneurship and industrial growth.

By implementing wholly or partially some of the above recommendations, Zimbabwe can foster a culture of innovation, entrepreneurship and industrialization that can lead to economic growth and development.

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