Practical Work in Science and Mathematics Education in Zimbabwe

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Preface

The ongoing discourse on enhancing science and mathematics education through experiential, contextually grounded methods in Zimbabwe is being furthered by Practical Work in Science and Mathematics Education. This book is driven by the increasing recognition that hands-on, inquiry-based learning is essential for comprehending and implementing scientific and mathematical concepts, particularly in the context of Zimbabwean learners and educators' lives.

There are five chapters in the book. Chapter 1 delves into the history of practical work in science and mathematics education from the colonial era to present-day Zimbabwe, exploring policy shifts, curriculum reforms over time, and pedagogical transitions. The second chapter explores the theoretical foundations of theory, utilizing constructivist, experiential, and competency-based learning theories to guide practical teaching methods. The third chapter delves into the significance of practical work and explains how it contributes to the development of scientific proficiency, mathematical knowledge, and critical thinking.

The fourth chapter examines the assessment of real-world tasks, presenting models and techniques that reflect the Zimbabwean curriculum's commitment to authentic and ongoing evaluation. The article underscores the significance of incorporating formative and summative assessments into classroom instruction to enhance learner engagement. Chapter 5 addresses challenges to practical work, focusing on systemic, infrastructural, cultural (test-based) development and professional development that interfere with the effective delivery of practical learning.

The purpose of this book is to assist educators, curriculum developers, policymakers and researchers, as well as teacher educators in enhancing science and mathematics education in Zimbabwe that is focused on the student and their context. It provides both theoretical and practical guidance, with the objective of bridging the gap between curriculum intent and classroom reality. Moreover, it confirms the importance of practical work in preparing learners not only for exams but also for life, innovation and development in Zimbabwe and globally.

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Chapter 1: A historical overview of practical work in Science and mathematics in Zimbabwe

1 Introduction

As transdisciplinary knowledge becomes more ingrained and society's demands shift, we are now living in an age of synthesis that has been shaped by the Fourth Industrial Revolution (4IR) and marked by new professions (Tsakeni, 2022). A growing consensus is that STEM education plays a vital role in preparing people for these emerging professions (Nadelson & Seifert, 2017). Du Plessis (2018) pointed out that STEM-related skills are essential in all fastest-growing professions in the 4IR. Due to the practical and impactful nature of STEM education, educators often emphasize teaching and learning in contexts that are both real and participatory (Srikoom et al, 2018).

Practical work is a valuable technique for creating authentic learning environments, as it allows learners to engage in both experiential and experiential learning (Tsakeni, 2022). The scope of practical work in STEM education is based on learner-centered activities. These may involve field trips, experiments (such as hydroponics), scientific investigations) or online research; other work in progress at the laboratory; model construction; technical drawings and simulations; or work-integrated learning experiences (Tsakeni, 2022). These activities are commonly conducted in structured settings like classrooms, science labs and workshops. Even so, hands-on learning can occur in outdoor settings or in natural environments, expanding the scope of possibilities (Tsakeni, 2022).

Practical work in STEM education, despite its pedagogical value, can be costly due to the ongoing need to replace consumables and maintain fragile equipment, as specified in certain curriculum frameworks (Tsakeni, 2022). Teachers are expected to adapt when the suggested resources and tools are not accessible, by utilizing locally available resources, using experimental procedures, and seeking innovative alternatives to standard hands-on activities (Tsakeni, 2020).

2 Science and Mathematics in Zimbabwe context

The importance of Science and Mathematics education in preparing human capital for the future has been widely acknowledged on a global scale. The central role of science and mathematics subjects in education in Zimbabwe is to develop learners' literacy in scientific, mathematical, and technological fields, while also fostering their creativity. Zimbabwe has adopted an experiential and application-oriented approach to teaching and learning since achieving political independence in 1980 (Chirinda et al., 2023).

Before Europeans arrived, technical education was an integral part of every African community and wasn't just a responsibility of designated teachers. Instead, it was a collaborative effort that involved all adults participating. Nyerere (1967) and Peresu and Nhundu (1999) both remarked that technical education before colonialism was informal, lacking the rigid timetables and structured classrooms typical of modern education. Learning was a natural outcome of daily activities, play and work in the community (Chiweshe et al., 2013). Older men and women imparted survival and practical skills that enabled the younger generation to make optimal use of natural resources. The children developed these abilities by observing, imitating, and practicing until they could precisely copy what they had observed. Boys received training in various fields such as hunting, blacksmithing, carving, livestock raising and house construction from their fathers, while girls grew up with domestic tasks like cooking, weaving, pottery and other household crafts taught by their mothers. The indigenous technical education system fostered social integration, conserved cultural knowledge and encouraged a robust sense of identity among Africans before colonization (Shizha, 2006).

Secondary education in Zimbabwe underwent a systemic reformation during the colonial period, with F1 and later F2 tracks (Kanyongo, 2005; Nyaumwe, 2006). The F1 stream was designed for a few students with limited academic abilities, while the F2 stream provided practical training to most students who were not qualified for higher education (Kanyongo, 2005; Nyaumwe, 2006). As per Bergmann (2003), colonial and mission schools in numerous African areas often included practical subjects during their initial years of establishment, frequently through agricultural and vegetable practices. Girls were typically taught about domestic science and art/craft during the colonial period, while both genders participated in agriculture or gardening. Zvobgo (1994) contends that the negative perception of practical subjects in technical education was caused by racist ideologies, which were perpetuated through colonialism. As Mungazi (1990) notes, while theoretical courses were required in black students, and the curriculum was rudimentary with minimal scientific content, unlike the more advanced technical training available to white students. Due to the unequal and discriminatory nature of the system, Africans were resentful and harbored against the education system established by colonial rulership (Kanyongo, 2005). Following their independence, the majority of Francophone African nations abandoned the colonial-style technical education system, while former Anglophone countries like Zimbabwe attempted to reform and adapt it to better serve their populations.

In Zimbabwe, mathematics and science have traditionally been considered both academic and practical subjects that require hands- on participation by learners (Nyaumwe, 2006; Pakombwele, 2023). Academic science and mathematics is a concept that originated with the ideals of ancient Greek philosophers, including Aristotle and Plato, who focused on theoretical learning through logic and reasoning (Nyaumwe, 2006). This type of science and mathematics was deemed necessary for the training of future leaders and clergy. In comparison to other professions, practical science and mathematics was aimed at manual laborers, who were frequently seen as lacking academic expertise but required hands-on learning for their livelihood. Colonial education in Zimbabwe embraced a Greek dichotomy, keeping the academic and vocational science and mathematics distinct from each other (Shizha, 2006). In F1 secondary schools, students who demonstrated academic prowess were placed and enrolled in theoretical science and mathematics classes. F2 schools were designated for students with weak academic backgrounds and taught science and mathematics in applied fields such as accounting, finance, commerce, agriculture, construction, welding, and mechanics (Nyaumwe, 2006).

Zimbabwe's inclusive education philosophy was established in 1980, coinciding with political independence and advocating for equal educational opportunities (Chiweshe et al., 2013; Nyaumwe, 2006; Shizha, 2006). This approach sought to eliminate the barriers that had previously characterized students' perceived academic ability. Hence, the F2 system was eliminated, and all students started attending F1 secondary schools, regardless of their academic status. The modification allowed for the inclusion of a common science and mathematics curriculum, creating equal opportunities for all individuals to work in the economy. This change also enabled competitive job prospects for citizens (Nyaumwe, 2006).

Within the first five years of Zimbabwe's independence, the country shifted its education system from academic to practical and scientific socialism (Chimbunde & Moreeng, 2024). The Minister of Education's statement in 1985 was a clear example of this change, as it called for the curriculum to be used as if it were an instrument for building societal social progress, emphasizing scientific and technological knowledge to improve productivity (Chimbunde & Moreeng, 2024). The foundation of this vision lay in the philosophy of Education with Production that sought to combine academic knowledge with practical experience. It was designed so that the pupils could use theoretical knowledge to solve practical problems, improve their living conditions and positively change their surroundings (Chimbunde & Moreeng, 2024). A strong foundation exists from science and mathematics education for technical and vocational education. Hence, science and mathematics education has been mainly found in the educational curriculum. If taught properly, learners are facilitated with conversion of science and mathematics into enhanced technologies for the betterment and enhancement of society (Bhukuvahani etal., 2023).

While this philosophy was full of ambition and noble intentions, it had a number of problems in practice. A significant problem was the inconsistency of policy intent and classroom practice. A lot of teachers mistook the philosophy for something else for instance, agricultural activities such as vegetable planting or small livestock, which were associated with vocational training during the colonial period but Africans had long rejected (Chimbunde & Moreeng, 2024).

Despite its noble intentions, the Education with Production program was widely rejected, particularly by black communities, who associated it with the F2 movement associated with the colonial era technical and vocational education system (Maravanyika, 2018). Education with Production was seen by many as a continuation of the efforts to prepare black students for working in white owned factories and farms instead of academic or agricultural positions (Bhukuvhani et al., 2023). Therefore, academic education was still the most favored option for most.

However, in 1999 the Presidential Commission of Inquiry into Education and Training proposed a departure from an academic curriculum towards an outcome-based model that valued both technical and vocational competencies equally (Nziramasanga, 1999). Zimbabwe's Government, in 1999, established the Presidential Commission of Inquiry into Education and Training, with Dr. Nziramasanga. The education which had been largely passed down from the colonial era and was no longer relevant to Zimbabweans. The education system in Zimbabwe remained focused on academic subjects and evaluated only minorities, who had personal experiences, aspirations, and financial needs.. Consequently, the Nziramasanga Commission was charged with conducting a comprehensive review and proposing alterations to education that would better align with the national development objectives (Nziramasanga, 1999). Nziramasanga (1999) recommended a change from primarily content-heavy, examination driven curriculum to mainly practical, skills-oriented, outcome-based education (OBE) model with hands-on learning in science, maths, technology and vocational training.

One of the primary conclusions of this Commission was that the education system in Zimbabwe was still elitist and focused on theoretical aspects, with little regard for practical skills (Nziramasanga, 1999). Practical subjects like agriculture, technical graphics, metalwork, and domestic science were frequently overlooked. Under-resourcing or underutilization of laboratories was common in science and mathematics education, which resulted in students learning the material through rote memorization rather than through experimental investigation and practical application. Nziramasanga (1999) acknowledged that practical learning was crucial for Zimbabwe to achieve economic transformation and meet the demands of a technologically advanced world.

In order to overcome these limitations, the Nziramasanga Commission suggested implementing a curriculum, which would ensure that all learners acquire not only theoretical knowledge but also practical skills and competencies relevant to their lives and careers (Nziramasanga, 1999). Learning outcomes were established using the following framework; Learner's ability to perform a task with the acquired knowledge and that mathematics and science subjects were expected to involve problem-solving, experimentation, data analysis, critical thinking, innovation.

Furthermore, Nziramasanga (1999) suggested placing equal emphasis on four fundamental aspects of education: science, mathematics, technology and vocational education. This marked a departure from the colonial legacy of vocational and practical subjects being seen as secondary to academic weakness. In contrast, Nziramasanga (1999) promoted practical learning to be regarded as equivalent to academic learning, emphasizing its significance for national progress, employment, and self-reliance. Nziramasanga (1999)’s recommendations aimed to eliminate the traditional separation between academic and technical education and to promote a more diverse, equitable, and comprehensive system of education.

The planned integration of practical elements into all curriculum areas was a major policy shift that was inspired by (Nziramasanga, 1999). Science instruction involved the utilization of well-equipped labs for student experimentation and investigative learning. Mathematics education was to be enriched by practical problems, real-world applications like budgeting, measuring, and modelling, as well as the use of technology to visualize abstract concepts. It was also suggested that Information and Communication Technology (ICT) should be integrated into science and mathematics instruction to enable the use of simulations, virtual experiments, and access to digital learning materials (Nziramasanga, 1999).

To implement the new practical pedagogies, educators must undergo teacher professional development, as recommended by Nziramasanga (1999). The approach involved imparting practical knowledge, utilizing laboratory facilities, employing ICT technology, and creating legitimate evaluations with tangible outcomes. Furthermore, Nziramasanga (1999) suggested redeveloping school facilities to include: science laboratories, technical workshops, agricultural plots and computer labs for hands-on learning. Innovative approaches to ensuring equity and access were suggested in rural and under-resourced schools, including the use of mobile laboratories and community-based learning projects.

The Commission emphasized the importance of continuous assessment methods that surpass conventional exams to gauge learners' practical knowledge application (Nziramasanga, 1999). They suggested alternative methods such as portfolio assessments, performance tasks and project-based learning to assess the scientific and mathematical competencies of learners in real life scenarios. Teachers could use these assessments to track learner progress, identify gaps, and provide targeted support, which would lead to a more responsive and learn-centred education system.

In 2015, the Ministry of Primary and Secondary Education (MoPSE) introduced a new curriculum framework that was heavily influenced by the Nziramasanga Commission. In the 2015 curriculum reform, there was a strong emphasis on Competence-Based Learning, with Science being particularly favored. This approach also included practical and vocational learning areas like Agriculture, Design and Technology, and Visual (and Performing Arts). Practical knowledge is no longer a peripheral aspect of this modified curriculum, but rather embodies the fundamental principle of teaching and learning. In line with recommendation, the competency- based school curriculum had a science, mathematics, technology, and vocational education bias (MOPSE, 2015).

The drive for practical work in science and mathematics was also a factor driving the national economic agenda. Despite the ongoing problem of youth unemployment and underemployment in Zimbabwe, it was increasingly expected that graduates with entrepreneurial mindsets, problem-solving skills or innovation would develop within the education system. There is a direct connection between practical learning in STEM and wider socio-economic goals, such as industrialization, food security, and technological advancement.

Nziramasanga Commission's vision of progress had several obstacles that hindered the implementation of the proposed curriculum and practical learning. Several schools were not equipped or able to support hands-on learning. In-service training for teachers was frequently subpar, and there was a dearth of teaching and learning materials. Additionally, written exams were still given more emphasis in the examination system, which hindered the transition to practical evaluation.

The Zimbabwean education system began to prioritize improving the quality and relevance of education over overall planning and efficiency during the early 1990s, with a focus on targeted reform from the mid-2000s. The era witnessed substantial transformations in the delivery of education, teaching approaches to instruction, the integration of new technologies, and the enhancement of job readiness competencies

(Chimbunde & Moreeng, 2024). This culminated in implementing both the STEM approach and the mathematical method (MoPSE, 2015).

Rising unemployment further accelerated the call for educational reform. To meet evolving national development goals, then-President Robert Gabriel Mugabe emphasized the need to reform education system structure and curriculum as soon as possible (Chimbunde & Moreeng, 2024). The outcome was a renewed emphasis on STEM education, youth empowerment and entrepreneurship. Reforms were introduced by the Ministry of Primary and Secondary Education to provide students with hands-on experience as well as basic professional skills in order to promote entrepreneurship and contribute to national socio-economic development (Chimbunde & Moreeng, 2024).

Traditional understandings of education were challenged by this paradigm shift, which prioritized content knowledge over practical skills and critical thinking (Chimbunde & Moreeng, 2024). This larger transformation involved the restructuring of higher education as well. In order to better align education with national development, universities should have five key objectives: teaching, research, community service through volunteering and collaboration, innovation by professors, and industrialization (Murwira, 2019). In line with this, Mudondo (2020) emphasized that curricula should be redesigned to promote the production of goods and services, aligning education with the goals of modernization and industrialization.

Competence based curriculum

Zimbabwe's teaching and learning paradigm underwent a major change when the Ministry of Primary and Secondary Education (MoPSE) introduced the Curriculum Framework for Primary and Secondary education (MoPSE, 2015). The reform was based on the recommendations of the Nziramasanga Commission (1999) and promoted Competency-Based Education (CBE), which were previously criticized for being too focused on academic subjects in education. The CBC was the focal point of this reform, which aimed to harmonize education with national development priorities, global education trends, and skills demands of the 21st century.

According to the CBC, education should surpass theoretical learning and embrace practical applications such as critical thinking, creativity, innovation, collaboration, entrepreneurialism, and problem-solving (MoPSE, 2015). This system differed from the previous one that prioritized content memorizing and written exams, frequently disregarding hands-on learning. Moreover, Education under the CBC aimed to develop competencies, which include a variety of knowledge, skills, values, and attitudes that learners must apply in different contexts for meaningful contributions to society.

Science and mathematics were reimagined as not just academic fields, but also as practical and dynamic fields that are crucial for economic expansion, technological progress or sustainable development (MoPSE, 2015). This meant that innovation, industrialisation and job creation could be promoted through the reform using Science, Technology Engineering, and Mathematics (STEM). As a result, the CBC changed the teaching of science and mathematics to give greater emphasis to learning in reality through inquiry, experimentation, and application of real-life problems.

In science education, the CBC developed an instructional model that requires students to conduct hands-on experiments, learn through projects and work in field conditions (MoPSE, 2015). The students are prompted to participate in laboratory and outdoor experiments, test, analyze, and draw conclusions from these observations and hypotheses. They introduced the integration of local and indigenous knowledge systems as a means of contextualising scientific learning within the context of socio-cultural and environmental conditions in Zimbabwe (MoPSE, 2015). As an illustration, students may delve into traditional herbal medicines or local agricultural practices and compare them with modern scientific explanations and techniques.

Science laboratories, mobile science kits, and affordable teaching aids were emphasized by the CBC to support this hands-on learning (Gory et al., 2021; MoPSE, 2015). Despite being unevenly trained in inquiry-based learning, teachers are now seen as facilitators rather than imparters. Students are expected to actively engage in scientific inquiry, experimentation and collaboration on scientific issues. The CBC supported the use of functional learning methods in mathematics, emphasizing the importance of exploring how mathematical concepts can be applied to real-life scenarios and problem-solving. The emphasis on theoretical concepts and methods was shifting to practical areas such as managing household finances, gauging land and buildings, modeling trends, and analyzing business processes. Additionally, the course included mathematical activities and simulations that enable learners to generate and analyze data, construct mathematical models, and utilize digital tools for analysis and visualisation.

Additionally, CBC implementation saw the inclusion of numerous cross-curricular STEM projects that enabled students to use scientific research and mathematical reasoning to tackle diverse problems across disciplines (MoPSE, 2015). Depending on the project, science and mathematics projects may involve designing a basic irrigation system, developing swathes of solar energy, or monitoring environmental pollution. Each endeavor necessitates the use of mathematical methods, scientific research, and technological advancements.

A notable development in this regard was the integration of practical work with formal assessment under the CBC (MoPSE, 2015). In the old system, assessments consisted mostly of summaries and theories, and often neglected to account for learners' real-world skills or application of knowledge. The CBC enforced the use of continuous assessment and practical examinations as mandatory elements in the evaluation process, particularly in science courses at the junior and senior secondary levels (MoPSE, 2015).

MoPSE introduced the competency-based curriculum assessment framework document that highlights the continuous assessment learning activity (CALA) (MoPSE, 2021), for Upper six students, Grade seven, and Form 4. CALA refers to different learning activities or assessments that are documented and enable learners to undertake comprehensive research-based tasks in particular fields where they incorporate practical activities in real-world applications such as collecting data through manual methods (Mashoko, 2023).

Students are evaluated on their aptitude for conducting experiments, recording observations, analyzing data, and reporting outcomes (Mashoko, 2023). Students in mathematics are expected to solve real problems and demonstrate their reasoning and process, rather than just providing the correct answer. These practical components are designed to reinforce the importance of skill implementation and to ensure that students finish with demonstrable skills rather than just theoretical knowledge.

Practical work is evaluated through a range of methods, including tasks focused on performance-based issues (performance analysis), portfolios and research projects (Mashoko, 2023). A more comprehensive view of student achievement is provided by teachers who are trained to observe and record their competencies over time. The education measurement in Zimbabwe is being redefined to align with international standards and competency-based education best practices.

Institutional and policy support is crucial for CBC's practical work promotion. MoPSE (2015) introduced policies that aimed to revitalize science laboratories, integrate ICT into teaching and learning, and promote the hiring of teachers qualified to teach science and mathematics during the service. A focus on teacher professional development was given - with workshops and training modules on CBC implementation, practical assessment, and learner-centred instruction being offered nationally (Pakombwele & Tsakeni, 2024)..

Zimbabwe's educational policy incorporates Information and Communication Technology (ICT) as a means of encouraging practical learning (MOPSE, 2015). In 2015, the curriculum reform introduced ICT as both a subject and an integrated theme in all subjects, including science and mathematics. Teachers can incorporate simulations, virtual experiments, digital labs and mathematical software into their teaching to make the learning more practical (Pakombwele & Tsakeni, 2024). The objective is to make science and mathematics more interactive, accessible, and reflective of 21st-century skills by utilizing digital tools (Pakombwele & Tsakeni, 2024).

Even so, these initiatives have encountered obstacles. The underfunded schools and rural settings are proving to be critical in the struggle to achieve CBC goals due to resource constraints. Many schools still lack the basic infrastructure, equipment and materials needed for hands-on science and mathematics learning.. Additionally, the varying levels of implementation of CBC across the country can be attributed to the uneven training of teachers. In spite of this, the CBC has demonstrated remarkable success in turning classrooms into engaging learning environments when it is used correctly.

Practically speaking, the CBC aligns with the national vision for Education 5.0, which emphasizes teaching, research promotion, community service and innovation in education, as well industrialisation. It is anticipated that the education system will produce graduates who are not solely job seekers but also productive laborers. The practical application of science and mathematics is deemed essential in preparing learners for active participation in Zimbabwe's socio-economic development.

Students' employability is improved by the CBC through practical training, which fosters innovation and create confidence in their future careers. The students' education enhances their skills and prepares them for important career fields such as engineering, technology, health sciences, data analytics, and entrepreneurship, which are crucial for Zimbabwe's modernisation and industrial transformation.

Education 5.0 and heritage-based curriculum

Education 5.0 was introduced by Zimbabwe to address long-standing national issues, such as high youth unemployment, de-industrialization and the global shift to knowledge-based economies (Tagwira, 2019; Chirinda et al, 2023). The Ministry of Higher and Tertiary Education, Innovation, Science and Technology Development (MHTEISTD) introduced Education 5.0 in 2019, which marks a significant shift from traditional education models by expanding the number of core functions available to higher education institutions from three to five which includes Teaching, Research, Community Service, Industry, and Industrialisation (Tagwira, 2019; Chirinda et al, 2023). Besides reconceptuting the role of higher education in national development, this innovative approach also extends it beyond tertiary education to primary and secondary education through the Heritage-Based Curriculum, which underscores the application of knowledge in real-world applications, particularly in science and mathematics.

With the Heritage-Based Curriculum, Education 5.0 transforms learning into a practical, hands-on, and problem solving process that generates economic and social productivity (Tagwira, 2019; Chirinda et al, 2023). Science and mathematics, which were once taught through abstract, textbook-based methods, are now being repositioned as drivers of innovation and industrial transformation. This policy ecosystem promotes practical work in schools, equipping students not only with theoretical knowledge but also with the skills to design, evaluate and implement solutions to problems that impact their communities and the wider Zimbabwean community (Chirinda et al, 2023).

The core principle of Education 5.0 is that universities and colleges should play a crucial role in Zimbabwe's industrialisation by producing goods and services, not just graduates (Tagwira, 2019; Chirinda et al, 2023). This mandates a set of learners who possess not just theoretical knowledge but also practical expertise in scientific and technological issues.' Thus, the secondary and primary education systems have started to conform to the standards of tertiary institutions, incorporating STEM-based, hands-on learning techniques that are in line with the outcomes of Education 5.0. Education 5.0's objectives have led to the redesign of science and mathematics education as being based on the principle of learning by doing. Scientific pursuits involve prioritizing experimentation, observation and data collection over analysis (Mashoko, 2023). The emphasis on inquiry-based learning is evident in the way students engage in questioning, hypotheses testing, and structured experimentation acquiring knowledge about scientific phenomena (Pokombwele, 2023). The practical task can involve basic biological experiments, chemistry tests, or physics demonstrations with everyday materials, all of which are designed to be resource-efficient but also pedagogically valuable.

Mathematics is no longer limited to abstract problems on chalkboards (Ado & Abasi, 2014). Rather than other approaches, learners are encouraged to apply mathematical concepts to practical issues like costing, building parameters, information gathering, and business analysis. The syllabus emphasizes the use of mathematical modelling, financial literacy projects, simulations, and community-based surveys that require data collection, graphing, or analysis. Additionally, there are workshops on ecclesiology.

This paradigm shift has led to a modification in assessment practices. Practical assessment components are now integrated into public examinations at both junior and senior secondary levels. Scientists evaluate students' proficiency in conducting experiments and reporting them, whereas math students are evaluated on their modelering skills and problem-solving abilities through project assessments. Both fields. This institutional commitment is strong, and these reforms make sure that learning outcomes are based on competency and applicability.

The Ministry of Primary and Secondary Education (MoPSE) has developed a Heritage-Based Curriculum that complements Education 5.0 by providing an opportunity to learn in Zimbabwe's cultural, historical contexts while also acknowledging other world cultures. Its teaching ethos emphasizes the importance of not only learning about current issues but also understanding and applying them in light of their own heritage, values, and everyday life.

A focus on heritage in science and mathematics promotes contextualised learning (Mapara, 2009; Chirinda et al, 2023). Students may examine ancient techniques like water harvesting systems, herbal remedies, or indigenous architecture, and compare them with contemporary scientific approaches. A link between indigenous knowledge systems and scientific inquiry is created by this, which validates the cultural roots of learners while also fostering scientific literacy.

Furthermore, students are prompted to participate in projects that tackle local issues, such as waste management, energy production using local materials, or agricultural optimisation, by employing scientific and mathematical approaches. The focus on relevance and context allows for a more meaningful interaction with the community, which contributes to sustainable development.

Conclusions

Zimbabwe's history of practical work in science and mathematics education is characterized by a complex interplay between cultural roots, colonial legacy, policy changes, and changing global educational norms. Throughout history, practical learning has been a crucial aspect of education in Zimbabwe, with periods marked by its colonial history and the presence of racially segregated and vocationally stratified education systems. Through a dual-track system that reinforced social inequalities, the colonial F1/F2 dual track created ambiguity between academic and vocational learning. Even so, the achievement of independence by 1980 demonstrated a trend toward education that was both socially responsive and inclusive. The introduction of the Education with Production philosophy was a prominent movement in the early 1980s to bring practical education back into mainstream schooling, with the aim of aligning education with national development goals. The Nziramasanga Commission of 1999 revolutionized the landscape by promoting a more comprehensive and focused curriculum that strengthened science, mathematics, and technology's contribution to improving national progress and job prospects. Competency-Based Curriculum (CBC) launched in 2015, which formally combined practical tasks with hands-on experiments, project-based learning, and practical applications. The CBC acknowledged the importance of teaching science and mathematics in terms of experiential, contextually relevant, and inquiry-based learning to ensure knowledge and practical skills are acquired by learners.

The advent of Education 5.0 reinforced the implementation of five pillars: education, research and community service; innovation and industrialization. It broadened the scope of practical education to include tertiary education, positioning science, mathematics, and STEM education as catalysts for innovation and economic transformation. By emphasizing the importance of teaching industrial and entrepreneurial skills, Education 5.0 enhanced the integration of practical learning with improved laboratory infrastructure. It also introduced robotics technology, coding, internships, and real-world implementation of classroom knowledge.

In tandem, the Heritage-Based Curriculum promoted the use of local knowledge systems, indigenous science and community-based problem-solving to contextualise practical. The practical work is emphasized as not solely focused on scientific method or laboratory skills, but also on motivating learners to create innovative solutions that are grounded in their socio-cultural contexts. Contemporary education policies now emphasize authentic, hands-on, and minds-on learning utilized through fieldwork, experiments, model building, simulations, and digital integration.

Poor infrastructure, inadequate teacher training in practical methods, and resource limitations are common issues faced by many schools, especially those located outside of urban centers. Nevertheless, Zimbabwe's policy path shows a consistent effort to overcome these barriers and make practical work an essential component of its pedagogical and developmental approach.

To sum up, the progress of practical work in science and mathematics education in Zimbabwe is a tale of both adaptation and change. This point to a national drive to build an inclusive and responsive education system that is also innovative. With the nation's socio-economic aspirations and global education trends, advancing practical skills across all levels of education is crucial in producing future problem solvers, innovator leaders and participants in national development.

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Chapter 2: Theoretical underpinnings in Science and Mathematics Practical work

1 Introduction

Practical work has been deemed essential to effective teaching and learning in science and mathematics education. Practical work acts as a conduit for the concrete realization of abstract ideas, connecting theoretical concepts to practical applications. Laboratory experiments, fieldwork, simulations, and investigative activities are common in science education, while mathematics involves model-building, manipulatives (such as computer programs), mathematical investigations, or application-based tasks. Additionally, practical work is involved in the curriculum. Although practical work is widely regarded as valuable, its execution varies greatly across different settings, frequently without a consistent theoretical framework. As a result, there have been discrepancies in learning outcomes and the absence of opportunities to cultivate critical thinking, creativity, and problem-solving.

The need for a firm theoretical basis in the design and execution of practical work has become more important as reflected in global educational reforms that aim for competency-based, inquiry–driven and STEM integrated pedagogical practices. Constructivist, experiential, and sociocultural theories have impacted our comprehension of how learners construct knowledge through doing, observing, reflecting, and collaborating. Notwithstanding this transformation, there is still a gap in systematic expression of these theories to guide the design and execution of practical tasks in science and mathematics classrooms.

The focus of this chapter is on the theoretical foundations that support practical work in science and mathematics education, with a focus on developing specialized structures to integrate key epistemological, pedagogical, and contextual elements. The model use major learning theories such as constructivism (based on a cognitive model), experiential education, inquiry-based learning and socio-cultural theory to describe the structure of practical tasks which can help them understand concepts better, develop procedural knowledge, and use scientific or mathematical reasoning in decision making.

This chapter aims to provide educators, curriculum designers, and policymakers with a solid understanding of the theoretical model that informs practical work in order to enhance the integration of practical components in teaching and learning. The aim isn't just to boost students' engagement and success in science and mathematics but also to ensure that practical experience has a significant impact on the development of skills and lifelong learning competencies. The model serves as analogue and authentic alternative to theoretical teachings, with the understanding that practical activities are not isolated events or experiences but part of some important aspect of learning.

2 Practical work in science and mathematics education

In several nations, the teaching of science and mathematics has emphasized practical work as a crucial educational strategy (Shivolo & Mokiwa, 2024; Oliveira & Bonito, 2023). This category includes activities that involve learners observing, manipulating, or engaging with real-world objects, data, and materials, either alone or in groups (Shivolo & Mokiwa, 2024). While science education may involve laboratory or fieldwork, mathematics teaching typically emphasizes the use of manipulatives, practical problem-solving techniques such as problem solving and modeling models, mathematical investigations, and simulations grounded in everyday experiences.

Shivolo and Mokiwa (2024) and Oliveira and Bonito (2023) highlight that practical work can involve activities that provide learners with access to data and information about the natural or quantitative world which is beyond their immediate physical environment. Practical work in science and mathematics classrooms involves engaging students in real-life activities that aim to enhance conceptual understanding through hands-on learning. In science education, laboratory work is often used synonymously with practical work (Shivolo & Mokiwa, 2024), but in mathematics, a similar concept can be expressed through mathematical laboratories, interactive problem-solving tasks, and model-based learning activities.

The hands-on activities that teachers engage in while teaching students at the primary and secondary school levels have been dubbed practical work, which is also known as 'laboratory work' in science (Shivolo & Mokiwa, 2024; Oliveira & Bonito, 2023). Mathematics involves instructing students on practical and abstract math concepts, data analysis, geometric shapes, or the use of mathematical principles in solving real-world problems. Practical work has been recognized for its broad range of meanings, but it now encompasses more than just performing tasks, promoting inquiry, discovery, and deep engagement with disciplinary content (Shivolo & Mokiwa, 2024).

While practical work in science education has traditionally been focused on laboratory experiments, it now encompasses a diverse range of learning environments such as classrooms, outdoor areas, and virtual platforms (Shivolo & Mokiwa, 2024). Mathematical learning has evolved from traditional textbook exercises to interactive activities such as working with dynamic geometry software, participating in statistical and work-integrated learning groups, and incorporating real-world examples into the curriculum.

The laboratory, whether concrete or intangible, is regarded as a location where students can evaluate their ideas, engage in interpretation and critical thinking, and have meaningful interactions with the phenomena or problems they are investigating. Science relates this to the natural world's objects and processes(Shivolo & Mokiwa, 2024). Mathematics involves the use of abstract concepts, mathematical patterns, or spatial relationships by students who utilize logical reasoning and imagination to formulate and evaluate conjectures or solutions. Practical experience is utilized by both fields as a means for learners to construct meaning, rather than just following textbook explanations.

Many experts have posited that practical work in science and mathematics is concerned with a wide range of learner-centred experiences such as field investigations, laboratory experiments, mathematical modelling, real-life problem-solving tasks, simulations, drawing and constructing representations (Babalola et al, 2020; Oliveira & Bonito, 2023). These experiences foster learning through both hands-on and experiential methods, promoting skills like problem solving or inquiry which are necessary for modern-day proficiency.

In either discipline, practical work involves learners engaging with tools, manipulatives, or sources of information to construct understanding that goes beyond theoretical abstractions (Tsekani, 2020). Science, mathematics, and statistics all involve different types of inquiry, such as examining ecological systems, chemical reactions, geometry tools, or applying statistical analysis to real-life problems. Both experiences help to increase the engagement of learners and make content more meaningful and memorable.

The most significant advantage for science and mathematics learners is being actively involved in practical processes like design, investigation, reflection, and conclusion-making (Mashoko, 2023; Oliveira & Bonito, 2023). The teacher is not the source of knowledge in this situation. Practicing work can be conducted in individual, paired, or group formats, with some being teacher-initiated and the other being self-directed. In science, students could design an experiment on photosynthesis or collaborate in mathematics to create a budgeting plan using real financial data. The learning experience fosters a sense of shared responsibility, enhances communication abilities, and facilitates the identification of common interests across disciplines and social contexts.

While the benefits of practical work are widely accepted, its execution is challenging. The use of practical strategies is often hindered in science and mathematics by resource constraints, inadequate infrastructure, and limited teacher readiness. Also, work that is practical can be expensive due to the availability of consumable materials and technological advancements, as well as specialized equipment (Oliveira & Bonito, 2023). Teachers are often required to experiment with alternative methods or alternatives to hands-on activities, improvise using locally available resources (Tsakeni, 2020). Mathematical applications may involve the use of either personal household items for measuring activities or open-source software for modeling data sets.

Despite these difficulties, practical exercises remain an important component in improving learners' conceptual and procedural understanding (Oliveira & Bonito, 2023). Its significance in science and mathematics is not limited to theoretical instruction, but rather encompasses a crucial aspect of learning. Practical work, as described by Shivolo (2018), refers to any type of learner-centered activity that is used as a teaching and learning tool which include demonstrations, experiments, projects, and investigations. In both fields, practical work is a versatile and potent instrument due to its flexibility.

Despite the difficulty of explaining practical work in earlier literature, contemporary scholarship has come to an agreement on its meaning and scope. The current classification of practical work includes core activities, directly related activities (e.g, experiments and investigations), and complementary activities such as simulations and reflective discussions (Oliveira & Bonito, 2023; Shana & Abulibdeh, 2020; Wei et al., 2019).

The practical work is commonly viewed as a learning approach that incorporates constructivist principles, where learners are encouraged to engage with real-life situations to evaluate their understanding and enhance their comprehension of the material (Lee & Sulaiman, 2018). In science and mathematics education, this approach focuses on active exploration rather than passive reception, resulting in learners actively seeking meaning (Matorevhu, 2020). The implementation of hands-on, experiential learning practices in Zimbabwean science and mathematics classrooms is believed by experts to aid teachers in achieving key curriculum objectives. Students who engage in inquiry-based activities such as science experiments or mathematical problem-solving tend to have better conceptual comprehension and academic performance than those taught through traditional theory-heavy instructional methods (Lee & Sulaiman, 2018). The practical implementation of learning and the development of problem-solving and critical thinking skills are crucial for advancing Zimbabwe's 21st-century education. Experiential learning is encouraged in practical work which enables learners to discover realities not covered in textbooks, and allows them to apply concepts based on first-hand knowledge (Twahirwa & Twizeyimana, 2020).

3 Theories guiding practical work in science and mathematics education

Active, social, and contextualized learning are the main focus of science and mathematics education through theoretical frameworks. Constructivism maintains that learners acquire knowledge through hands-on experience and reflection, using practical work as a foundation for conceptual expansion. Cultural tools and social engagement play a crucial role in sociocultural theory, which suggests that learners need guided support within their Zone of Proximal Development. According to Social Cognitive Theory, students must model and observe their learning by using observational and modeling methods, with self-efficacy being a key factor in student engagement and persistence. These theories help to design meaningful, inquiry based activities in science and mathematics classrooms that foster critical thinking, collaboration, and practical application.

3.1 Constructivism

Jonassen and Landin (2002) argue that constructivism is a theory of learning that asserts that knowledge is constructed by the learner through active cognitive engagement. In their argument, Porta and Keating (2008) contend that our perceptions are not an accurate reflection of reality but rather a result of our conceptualisation, suggesting that constructivism is more accurately defined by perspective rather than theory or approach. Additionally, According to constructivist thinking, human learning is not passive, but rather active, with learners contributing to their development.

Treagust and Duit (2008) argue that constructivism is based on specific epistemological and psychological assumptions, and concerns the conceptualization and acquisition of knowledge. Learning is viewed as a personal cognitive process, where learners actively construct or invent meaning from prior experiences and ideas, according to this perspective. Constructivism is more of a philosophical viewpoint than primarily geared towards education.

The foundations of constructivist theory can be found in various fields such as philosophy, psychology, sociology, and education, encompassing two fundamental principles. The psychological principle maintains that learners don't just "absorb" information; rather, they "build new knowledge" through meaningful action (Zezekwa, 2016). The epistemological view maintains that cognition is a malleable process, allowing learners to construct realistic accounts of the world as they perceive it. Both principles stress the importance of students actively contributing to their development.'

The significance of constructivism in science and mathematics education can only be appreciated through the work of its founding scholars. Driscoll (2005) characterizes four primary figures. The philosophical theory of John Dewey, who lived from 1859 to 1902, is often referred to as constructivism. He opposed the practice of rote memorization and advocated for experiential learning, where students participate in practical, real-life tasks that promote creativity and teamwork (Dewey, 1916). The development of understanding through social engagement and inquiry-based learning was a key focus of Dewey's progressive education philosophy.

According to Lev Vygotsky's theory of social development, culture, language, and interaction are essential components that shape learning. He presented key messages such as the Zone of Proximal Development (ZPD) and scaffolding, which emphasizes that learners advance through collaboration with more knowledgeable individuals. According to Vygotsky, learning is social and cognitive development arises from guided interaction. According to Jean Piaget's theory of cognitive development, learners progress through four stages, sensorimotor, pre-operation, concrete operational, and formal operational. According to Piaget, learners can integrate new experiences with their existing knowledge through the concepts of assimilation, accommodation, and equilibration. Science and mathematics education continue to rely on his dedication to active learning.

Discovery learning theory was introduced by Jerome Bruner (1915–2016), who argued that education is about building new knowledge through problem-solving and exploration. In line with Vygotsky's perspective, Bruner emphasized the importance of both active and social learning, with discovery education contributing to the development of creativity, critical thinking, and problem-solving skills (Bruner 2009). The teaching of science and mathematics in a constructivist manner has important implications for pedagogy. Learning is not a passive acquisition of knowledge, but rather an active participant in making meaning (Zezekwa, 2016). In constructivist schools, the emphasis is on real-world tasks, student autonomy, and collaborative exploration. This has contributed to the evolution of curriculum, especially in field work and other activities where students are involved in constructing scientific or mathematics.

Constructivist environments involve reconceptualised assessment. Driscoll (2005) contends that assessment is not viewed as a tool of responsibility by constructivists, but rather as an instrument to enhance learning and monitor cognitive development. Portfolios, group projects, reflective journals, debates and role plays are examples of methods that follow this approach (Zezekwa, 2016). In science and mathematics education, formative assessment is particularly important in evaluating practical work, which involves assessing learners' conceptual understanding, procedural skills, and problem-solving abilities.

Cakir (2008) draws on Piaget, Ausubel, and Vygotsky's theories to illustrate how constructivism contributeatons to conceptual change. According to him, effective learning requires learners to activate and restructure prior knowledge to make room for new concepts. This is particularly relevant in practical tasks, where students must apply theoretical knowledge in real-world scenarios.

In their work, Treagust and Duit (2008) suggest that the fundamental principles of constructivism are active construction leads to knowledge creation, not passive acquisition, understanding requires the importance of social interaction, conversations are initiated by discussing experiences and negotiating meaning, alternative frameworks, commonly referred to as "misconceptions," often need to be improved.

Science and mathematics education adopt constructivist teaching approaches that prioritize a learner-centered approach (Xu & Shi, 2018). The process of teaching is based on the acceptance of students' prior knowledge, beliefs, and experiences (Chuang, 2021). The use of these methods enables students to take ownership of their learning, as noted by Treagust and Duit (2009), which is crucial for achieving complete comprehension and lasting conceptual transformation.

Learning can be a challenge, as Cakir (2008) suggests, because students enter classrooms with worldviews that are deeply ingrained and often developed over many years. Hence, constructivist approaches to teaching science and mathematics must prioritize responsiveness, activity, and conceptual transformation over content delivery.

Constructivism is a powerful theoretical model for understanding and designing work in science and mathematics education. It encourages active, meaningful engagement with content by encouraging inquiry through collaboration and reflection (Zezekwa, 2016). It also changes the role of assessment from a performance indicator to an aid in learning. Through social interactions, cognitive conflict, and continuous refinement, the learners' pre-instructional conceptions are transformed into disciplinary understanding through an evolutionary process. Within the context of Zimbabwean education, science and mathematics education are crucial for national progress, and constructivist approaches provide a robust foundation for curriculum innovation, teacher training, or learner empowerment.

3.2 Social cultural theory

The sociocultural approach to learning, as proposed by Vygotsky (1978), highlights that knowledge is not solely transmitted between individuals, but rather constructed through social construction. Vygotsky (1978) stated that every aspect of a child's cultural development is approached from two perspectives: the social and individual aspects, which are first identified as interpersonal and then internal. In this view, learning is viewed as a social and communicative process that is deeply embedded in cultural and historical contexts. To understand how people progress in their learning within specific environments, Vygotsky proposed the Zone of Proximal Development (ZPD), which is the difference between a learner's ability to succeed independently and their ability to succeed with the guidance of fewer or more knowledgeable individuals (Cazden, 1981), depending on the context, such as a teacher, peer, digital tutor or well-structured learning activity.

The framework of ZPD for science and mathematics education includes collaborative problem-solving and peer-assisted learning activities. In contrast, learners who find it challenging to grasp abstract concepts can benefit from peer or teacher support, known as scaffolding, which provides structured and temporary assistance to help them complete tasks they cannot handle independently (Wood, Bruner, & Ross, 1976).

The sociocultural approach to education promotes a dialogic process that shapes learning and thinking through meaningful interaction. In order to understand learning, Mercer (2007) notes that human cognition is socially communicative and must be understood through communication. The presence of group discussions, verbal explanations and shared problem-solving tasks is particularly evident in science and mathematics education classrooms: it allows learners to articulate their ideas effectively while also challenging and improving upon prior knowledge.

Another element of importance in Vygotsky's sociocultural theory is mediation. Language, diagrams, symbols, and technological artefacts are the tools and signs that facilitate learning, rather than direct contact with the world (Lantolf & Beckett, 2009). The artefacts used in science and mathematics education may include manipulatives, graphing software (in the form of a diagram), or pre-recorded instructional videos. Learning about geometric constructions or algebraic operations through a video can be utilized as rehearsal aid in helping learners engage with real-life problems.

Also, words are considered the most crucial mediator, serving both as an intermediary (in communication with others) and a conduit for internal reflection. Language, in

Vygotsky's view, is central to the development of higher powers. This is evident in science and mathematics education learning, where students express their reasoning to others, justify solutions or engage in mathematical discourse, externalizing and internalizing math.

Scientific research suggests that sociocultural theory promotes the creation of interactive and collaborative learning environments, particularly in science education and mathematics, where meaning is negotiated through participation in cultural practices and shared cognitive tools (Packer & Goicoechea, 2000). Whether students are building geometric models, exploring number patterns or solving real-world problems, their understanding is mediated by the tools, language and social structures that frame it.

3.3 Social Cognitive Theory (SCT)

In 1986, Bandura created the Social Cognitive Theory (SCT), which is a continuation of his Social Learning Theory. The theory focuses on how people acquire knowledge through observation, imitation, and modeling. According to SCT, learning is not solely based on direct instruction but also depends on observation of others' behaviours and actions (Bandura, 1989, 2014). To learn new concepts or behaviors, students can rely on the instructional strategies of their teachers and observe them closely (Koutroubas & Galanakis, 2022).

Based on observed experiences, people create representations of themselves that inform future behaviour according to SCT (Schunk & DiBenedetto, 2020; Devi elided, 2017). It is common for educators to develop and utilize teaching methods based on their own learning. The theory emphasizes the significance of social contexts in shaping cognition, and therefore suggests that behaviour is influenced by the continuous interaction between personal, environmental, undoing, which is known as triadic reciprocal determinism.

The use of SCT as the theoretical framework for exploring how observational learning can enhance teacher development and instructional practice is explored in this study. Ifinedo (2017) acknowledges the teacher as a role model that can shape learners' understanding beyond mere knowledge transmission. Additionally, their behaviour and instructional approach are significant in this context. Learning is attributed to exposure to various social experiences, media, and interpersonal interactions.

In SCT, the concept of vicarious learning, which involves acquiring knowledge through observation, is a crucial idea. By using this method, learners can observe, internalize, and replicate behaviours without direct experience, which helps them to avoid errors and improve their performance (Beauchamp et al, 2019; Harinie & al:

2017). The four sources of self-efficacy that Bandura identified are mastery experiences, social modelling (vicarious learning), verbal persuasion and managing emotional & physiological states (Schlunk et al, 2017; Schunk und DiBenedeto, 2020). The use of social modelling in educational contexts is crucial due to its emphasis on observing demonstrations, receiving guidance, and mirroring effective behaviours.

SCT points out that learning does not always result in immediate behavioural change. The processing of observed behaviours and their relevance to one's actions are primarily dependent on cognition (Beauchamp et al, 2019). As a result, individuals' development is not solely determined by their upbringing and environment but also by how they internalize and reflect on observed experiences. By utilizing SCT in this study, the research emphasizes the importance of observation in shaping teachers' instructional choices and learners' engagement. This can be achieved through both observational and classroom behavior methods.

4. Integration of Constructivist, Social Cognitive and Sociocultural, into Practical Work in Science and Mathematics Education

Practical work in science and mathematics is an excellent vehicle for learners to actively construct knowledge, interpret abstract concepts, and translate these into practical applications. Learning is viewed as an active process that involves the construction of knowledge through experiences, as per the constructivist perspective and those of Piaget and Vygotsky. In mathematics and science practicals, this is demonstrated when students manipulate materials, interpret data, and reflect on outcomes to build mental models. Constructivism prioritizes inquiry, problem-solving, and discovery learning as the hallmarks of effective practical work.

Sociocultural Theory (Vygotsky, 1978) advances constructivist theory by placing learning within a social and cultural context. Rather than being an isolated cognitive event, learning is a constructed activity that is communicated through language/cultural devices and social interaction. The Zone of Proximal Development (ZPD) is a concept that emphasizes the use of scaffolding to facilitate learning transitions from assisted to independent performance, with guidance from teachers or peers. When engaging in science experiments or mathematical modelling, learners engage in activities that stretch their abilities and receive specific support.

In addition to this, Social Cognitive Theory (Bandura, 1986, 2014) stresses observational learning, modelling and self-efficacy. Students acquire knowledge through observing demonstrations, replicating processes, and receiving feedback in practical assignments. Student engagement in intricate experiments or problem-solving tasks is influenced by self-efficacy beliefs, which are formed through mastery experiences and vicarious learning. Learners are encouraged to persist and build confidence through social modeling and verbal encouragement.

These three perspectives advocate for a constructive, collaborative and reflective approach to practical work. They accept that learning takes place through actions, observations, interactions, and reflections, all within a meaningful social and cultural context. Instead of being passive, students are active agents that negotiate meaning through their surroundings and interactions.

To improve teaching and learning in science and mathematics classes, the Co-Constructive Practical Learning (CCPL) model (Figure 2.1) incorporates important ideas from Constructivism, Social Cognitive Theory, and Sociocultural Theory. Fundamentally, the approach views the teaching of science and math as a cognitively active, culturally contextualized, and socially mediated process. With the guidance of knowledgeable people in real-world settings, learners build knowledge through practical experiences, group projects, and observational learning. The model places a strong emphasis on the development of conceptual understanding through reflective practice, scaffolding, and vicarious learning. It encourages deeper learning and the meaningful application of mathematical and scientific information by supporting dynamic engagement between the environment, cognition, and behavior.

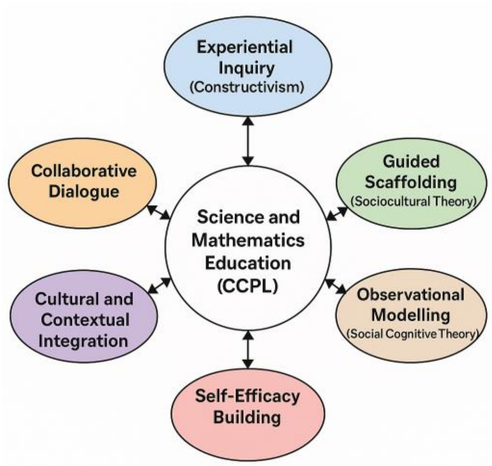

Fig 2.1Co-Constructive Practical Learning (CCPL) model

Experiential Inquiry (Constructivism)

The fundamental principles of constructivist learning centers on experiential inquiry where students engage in hands-on science and mathematics tasks exploring, investigating and interpreting concepts. Learning takes place through experimentation, material manipulation, and practical application rather than just passive information acquisition. This method promotes exploration, experimentation with theories and reflection in thinking. By engaging in practical tasks like experiments or modelling, students can integrate theory into their daily routines and acquire knowledge through action. The ability of students to construct meaning from their own experiences with physical and mathematical phenomena results in personalized understanding that enhances knowledge retention and application beyond the classroom.

Guided Scaffolding (Sociocultural Theory)

Vygotsky's theory suggests that learning takes place within the ZPD, as reflected in guided scaffolding. The concept is similar to this phenomenon. Teachers and peers act as better partners in practical science and mathematics tasks with the help of structured support. This support may involve asking questions, providing feedback, presenting demonstrations, or offering guidance to students in order to complete tasks they couldn't have done by themselves. The scaffolding is gradually removed as competence increases. Through this social mediation, students can gain more control over their learning and recognize the significance of language, tools, and collaborative interaction as mechanisms for developing concepts in real-life classrooms.

Collaborative Dialogue

Through structured peer interaction, conceptual development is improved through collaborative dialogue. Students engage in discussions about practical mathematics and science activities by sharing their observations, defending their reasoning skills, and explaining processes. The co-construction of knowledge and the resolution of misunderstandings are encouraged in these dialogues. Learning activities that involve group problem-solving or joint investigations provide opportunities for learners to express their ideas and compare approaches. The social interaction results in metacognitive awareness and deepening comprehension. It cultivates a culture of collaboration and critical thinking, which is necessary for scientific and mathematical reasoning. By engaging in discussions, students exchange ideas and come up with common understandings that contribute to greater personal cognitive growth.

Observational Modelling (Social Cognitive Theory)

The emphasis of observational modelling is on the process of learning by watching and copying, which is central to Social Cognitive Theory. In science and mathematics education, students watch teachers or competent peers explain procedures, strategies, and problem-solving techniques through demonstrations. Cognitive models for task approach and execution are established through visual and verbal cues. Learning new skills is facilitated by modelling, which reduces uncertainty and promotes self-assurance in applying it. Moreover, it facilitates the development of mental depictions of tasks before undertaking them by themselves. The use of realistic examples, thinkalouds, and real-time feedback is crucial in effectively modelling scientific and mathematical problems to guide learners through the process.

Self-Efficacy Building

Self-efficacy, or a learner's confidence in their performance, is essential for engaging and persisting in science and mathematics tasks. This is particularly true for the test subjects. The model employs strategies for improving self-efficacy, including mastery experiences, verbal encouragement, and emotional support. Practical activities are designed to ensure achievable challenges, which will help students achieve and feel successful. Peer and teacher positive reinforcement reinforces their capabilities. The use of reflective techniques like journaling or self-evaluation enables learners to identify and measure progress. Self-confidence is positively correlated with student success, as it fosters greater self-discipline, more challenging problems, and longer scientific and mathematical investigations.

Cultural and Contextual Integration

Cultural and contextual integration fosters relevance and meaning by embedding learning in students' lived experiences and environments. The design of science and mathematics tasks is based on examples, culturally-known tools, and problems from learners' communities. It recognizes different ways of knowing and values indigenous knowledge systems alongside formal curricula. This ensures that learners perceive their own reflection in the learning process, which can boost motivation and involvement. The process of cultural integration involves placing abstract ideas in practical, everyday situations, which enhances comprehension and facilitates transfer of knowledge. It ultimately links the classroom instruction with learners' social and cultural realities.

Conclusion

Constructivism, Sociocultural Theory, and Social Cognitive Theory are three important learning theories that have been studied in this chapter along with their applicability to practical work in science and mathematics education. It is clear from the suggested Co-Constructive Practical Learning Model that meaningful learning happens when students actively pursue their interests, get scaffolded support, work together with classmates, watch professional techniques, develop self-efficacy, and relate newly learned material to their cultural contexts. The model supports the notion that learning is a dynamic, socially mediated activity rather than a solitary cognitive process. Teachers may create inclusive, captivating, and productive practical learning settings that promote profound conceptual knowledge and lifelong scientific and mathematical thinking by incorporating these theoretical viewpoints.

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Chapter 3: The roles of practical work in science and mathematics education in Zimbabwe

1 Introduction

This Chapter focuses on the roles of practical work in science and mathematics education in Zimbabwe. From the beginning of the 18th century to date, educators and researchers have studied the value of practical work and its important role not only in science education but also in other subjects like Mathematics (Shana & Abulibdeh, 2020).The 1960s and 1970s was a period of major Science and mathematics curriculum development that made practical work in learning programmes more important (Bradley, 2005). Practical work in Science and Mathematics curricula has become the nucleus of curriculum reform initiatives which have taken placeworldwide(Gott & Duggan, 2007). The education system in Zimbabwe through its Heritage Based Curriculum (Education 5.0) has taken aboard the issue of practicals in Science and Mathematics education as a cornerstone in its bid to make science and mathematics teaching and learning responsive to global trends and expectations.The Heritage Based Curriculum (HBC) puts emphasis on the heritage based technological concepts acquired through a hands-on learner centered approach. Internationally, the value of practicals activities in Science and Mathematics education is widely recognized in countries like theUK, it is considered fundamental to STEM education (Gore et al., 2017).

2. PRACTICAL WORK

Practical works is any Science or Mathematics concept teaching activity in which students, working individually or in small groups, observe and/or manipulate objects or material they are studying (Millar, 2010). Generally, practical work refers to hands-on activities or exercises designed to apply theoretical knowledge in real-world or simulated environments. These activities provide hands-on experiences that complement theoretical instruction of knowledge, helping students develop skills in observation, manipulation, and critical thinking.

Manipulations of objects can take place in the school laboratories or out of the school settings, which is at the student's home, on digital and virtual learning platforms, or in the field (Millar, 2010). Practical work in Science and Mathematics education includes laboratory experiments, fieldwork, investigations, demonstrations, excursions and project-based learning activities (Fernandes, 2023). Laboratory work is defined by (Hegarty-Hazel, 1990)as a form of practical work taking place in a purposely assigned environment where students engage in planned learning experiences, and interact with materials to observe and understand phenomena. Investigations refer to practical work in which students are not given a complete set of instructions to follow but have freedom to choose the procedure to follow , format of recording and analysing data and also freedom to choose how to report data (Millar, 2010). These put the students in a position of a problem solving scientist. Practical investigations are especially important as they enable students to work back and forth between theoretical ideas and direct experience (Curriculum Corporation, 1994). Experiment is a form of practical work in which an intervention is involved to produce a phenomena to be observed or to test a hypothesis (Millar, 2010).

The Science and Mathematics syllabuses come with objectives for practical work. These objectives state the kind of skills that students are expected to acquire as a result of engaging in practical work. However there are some skills and knowledge which these students acquire intuitively during the practicals as part of the hidden curriculum. Therefore as the students work towards achieving the stated objectives they also acquire some skills and create knowledge effortlessly and unconsciously through intuition, accident and also through embodiment as they engage, manipulate and interact with the apparatus during practicals activities in the different learning environments including the labs.

3. THE ROLES OF PRACTICAL WORK IN SCIENCE AND MATHEMATICS EDUCATIONIN ZIMBABWE

There are interconnected, but separate, roles that practical work play in the teaching and learning of Science and Mathematics in Zimbabwe. The roles are generally based on the demands of the Heritage Based Curriculum particularly Education 5.0. The Heritage-Based Curriculum (HBC) in Zimbabwe focuses on five key pillars which are culture, innovation, education, economy, and sustainability. These pillars aim to equip students with skills and values for a holistic, learner-cantered approach that merges academic knowledge with practical applications, especially in the context of the Fourth Industrial Revolution (MoPSE), 2024).

The term role is defined in different ways in literature.Dudu (2014) views it as a sociological concept), describing it as a function of something in a particular situation. In this chapter, the term role means the use to which practical work can be put and the effect or impact it is expected to have when it is used in teaching and learning processes in Science and Mathematics education.

Some of theroles of practical work in Science and Mathematics education areplanned and have a clear set of intended outcome and impact. Some roles are not planned together with their effects and impact which may be positive or negative. They just emerge or are discovered as the practicals unfold when thestudents are working towards achieving the set objectives.The nature of the practical work depends on the objectives of the syllabus, the type of content, the way learning is taking place, and the reason why the practical is being done.

3.1. PRACTICALS AS ANINSTRUCTIONAL STRATEGYSCIENCE AND MATHEMATICS EDUCATION

In Science and Mathematics education in Zimbabwe, practicals are used as an instructional strategy in addition to other traditional teaching strategies such as lecture methods. Teachers are encouraged to use a combination of appropriate strategies to effectively engage challenge their learners through. The wide varieties of learning experiences associated with practical activities promote acquisition of scientific and mathematical expertise and understanding. Some practicals are used in demonstrations during the lessons as a way of enhancing clarity of concepts to the students.There is a lack of clarity and consensus as to the pedagogical basisfor practicals in science and Mathematics programs (Bradley, 2005).Students understand scientific investigations processes and grasp broad scientific and Mathematics concepts through hands-on experiences.Students achieve a deeper level of understanding by finding things out for themselves and by experimenting with techniques and methods (Shana & Abulibdeh, 2020). Research has shown thatstudents who are instructed through inquiry-based learning achieve higher scores than the ones who are instructed through traditional methods (Abdi, 2014). Constructivist theory of learning affirms that students like to touch things, to handle, prod, feel, and fondle objects for them to understand them.

3.2.PRACTICALS AS TOOLS FOR ACHIEVING INCLUSIVITY IN SCIENCE AND MATHEMATICS EDUCATION

In Zimbabwe, practical work is used as tools for ensuring inclusivity in science and Mathematics education. In practical activities ortho-didactic principles such as visual, tactual, self-activity are usually applied to cater for the diverse needs of students. Science and Mathematics learning occur in many ways that include talking, listening, reading, and drawing, making, enacting, experimenting, modelling, handling animals, rocks and tools, and using equipment (Shana & Abulibdeh, 2020). Practical lessons break the routine of lectures, providing a refreshing change that stimulates different senses and learning styles. Therefore practicals are used to cater for learners with different learning styles and special needs for example tactual,kinaesthetic,visual, auditory,cerebral, and olfactory. The scheme of assessment in Science and Mathematics in the Heritage based curricula is grounded in the principle of inclusivity and equalisation of opportunities (MoPSE, 2024). Teachers are encouraged to use a blend of appropriate teaching strategies that ensure equal access for students to Science and Mathematics concepts. The exclusion of practicals work from the Science and Mathematics teaching and learning processes would lead to social injustice among the students due to the high expectations linked to studying sciences and Mathematics(Tsakeni, 2018).

3.3. PRACTICAL WORK AS A TOOLS FOR CONCEPTUAL DEVELOPMENTSCIENCE AND MATHEMATICSINSTRUCTION

Practical work is used in Science and Mathematics education as a tool for elucidating theoretical concepts, making them more tangible and easier to comprehend. It also provides context for abstract ideas, helping students to see the real-world applications of their learning.(Rennie, Goodrum, & Hackling, 2001).Practical activities are widely regarded as pedagogical tools that strengthens conceptual understanding by encouraging personal observation and experimentation.(Tsakeni, 2018). Practicals provide students with concrete experiences and opportunities to manipulate ideas, which help them to make the abstract concepts more concrete and help simplify the complex concepts (Tamir, 1976).Such engagement supports not only conceptual understanding but also the development of scientific skills and higher-order thinking (HOT) abilities.

3.4. PRACTICALS AS TOOLS FOR DETERMINING WHAT TO TEACHIN SCIENCE AND MATHEMATICS EDUCATION

The feedback from Science and Mathematics practicals through reports determines the content teachers are supposed to teach in the respective subjects. An example can be when, practical work reveals the areas of weaknesses of the learners in the understanding and application of the Science and Mathematics concepts, and if the teachers identify them, they would definitely teach the concepts to avoid gaps in the syllabus coverage. Theory and practical work are interdependent and intertwined that it is difficult to separate them. Experiments assist in theory building and theory, in turn, determines the types of experiments that can be performed (Hodson, 1991; Tsakeni, 2018). Many educators do not recognize the interactive relationship of practical work and theory. Practical work can make teachers and students identify problems their possible solutions. These may be made components of the curriculum and syllabuses

3.5. PRACTICALS AS TOOLS FORTHEORY BUILDING INSCIENCE AND MATHEMATICS EDUCATION

Practicals are also used as tools for building theories that are used in Science and Mathematics education. Researchers and teachers make use of the data from Science and Mathematics practical work in their different academic researches in which sometimes they come up with very insightful theories, models, and principles. Sometimes the data is used to approve, disapprove, or even to improve some already discovered theories in Science and Mathematics education. The use of practicals in Science and Mathematics education for building of theory was also noted by (Hodson, 1991; Millar, 2004).Theory and practical work are inter-dependent. Practical work can be used to find facts that can be used to arrive at new principles (Millar, 2010).Practical work assist in theory building and theory, in turn, determines the types of practical activities that can be performed (Hodson, 1998). Laboratory activities appeal as a way of allowing students to learn with understanding and, at the same time, engage in a process of constructing knowledge by doing science (Tobin, 1990). Science and Mathematics educators should be encouraged to recognize the interactive relationship of practical work and theory so that they can effectively promote theory building. A theory is a framework of inferences that employ specific parameters and unambiguous terms, assumptions that are accepted as true and postulates together with their corollaries that are tentatively assumed to be true(Ausube, 1969; Driver 1983)

3.6. ILLUSTRATION AND VERIFICATION OF THEORIES AND CONCEPTS OF SCIENCE AND MATHEMATICS EDUCATION.

Practical work in Science and Mathematics education is being used to illustrate and verify facts, theories, principles, and concepts of science and Mathematics already taught to students. The verification may lead to the provision of foolproof recipes for practical work that would have misrepresented the nature of science and Mathematics to the students. This inculcates in learners the appreciation of the usefulness and applicability of some theories and principles not only in the study but in the real-life situations. The Zimbabwe Heritage based curriculum requires that learners recognised the usefulness and limitations of scientific methods and theories inclusive of those used in Mathematics and appreciate and challenge their applicability even in other disciplines and in everyday life. Wellington (1981) argues that Science and Mathematics courses often involve students working through a series of foolproof practicals work where the expected results are the same for everyone in the class if the instructions are followed correctly. In this case the goals of the practicals become getting the right answer rather that acquiring important skills.

3.7. PRACTICALS ASSCIENCE AND MATHEMATICSEDUCATION MONITORING TOOLS

Practical work is used asa powerful tool for monitoring the teaching and the learning processes of Science and Mathematics in schools.Practicals are used throughoutthe processes in form of practical assignments, practical tests and also as end of term and end of year internal practical examinations. Patterns and trends in performance ofstudents inform teaching strategies and student interventions.Ongoing observations on how student apply science and Mathematics concepts in real time and their misconceptions or gaps in understanding can be identified in time. The scores obtained by learners in these pieces of practical work would be analyzed to provide a continuous insight into any deviation from the expected standardsor benchmarkson student understanding,their skills development, and learning progress as a whole. In this way it enables correction and refocusing of the learning programme to ensure that the set objectives are achieved. This formative feedback associated with this role allows teachers to track skills development amongst the students and changes in their behavioral insights like the way they now solve problems as well as collaboration. Generally giving students a series of practicals would provide evidence of learning over time,for example repeated series of laboratory work would allow comparison to track on improvement, persistence, and mastery.Logs, journals, or practical reports help students reflect on what they learned, what went wrong, and how they can improve. Monitoring via practicals complements traditional tests and reduces overreliance on exams to judge student progress.

3.8. PRACTICAL WORK AS ANASSESSMENT TOOL.

Practical work in Science and Mathematics educations is also being used as assessment tools.In the HBC students are assessed through a continuous assessment system in the form of hands-on experiences, demonstrations and project type of practical work (MoPSE), 2024).Drumm, Bree, Griffin, and O'Leary (2024) also acknowledges the use of practical work as another effective way of assessing students.Theyare used as hands-on activities, experiments, or real-life applications to assess students' understanding, skills, and competencies in Science and Mathematics. The use of practical work for assessment moves beyond traditional written tests and focuses on the application of knowledge in practical settings.The use of practicals in assessment diversifiesstudents' assessment modes hence it broadens engagement with syllabus target competencies in bothScience and Mathematics education. This ensures that the principle of inclusivity and equalisation in assessment in both Science and Mathematics education as required by the Heritage Based curriculum issatisfied (MoPSE, 2024).

Information from Practical workcontribute to the data needed for assessment of students particularly when they are given as part of the continuous assessment activities to check on whether students are achieving or have achieved curriculum and syllabus objectives. Practical work is beingused as an assessment tool through portfolios, laboratory experiments, simulations, demonstrationsand Project Work. Demonstration involves performing a skill, such as connecting a circuit in science.A portfolio refers to collection of practical outputs over a period of time (Brooks & Brooks, 1999). Assessment can be made more effective by creating detailed and transparent criteria for scoring (rubrics). When practicals are used as assessment tools they reveal evidence of the behavioural traits acquired by the learner such as the ability to follow protocols, work under pressure, collaborate and the way thy solve problems. Although the use of practicals as assessment tools demands more resources like space, equipment, and time, it improves the authenticity of the assessment of the learners as it mirrors the real-world tasks. It also improves the inclusivity of the assessment of learners a sit allows learners with different learning styles to be meaningfully assessed i.e.visual, kinesthetic, and hands-on learners.

3.9. PRACTICAL WORK AS A TOOL FOR INSTRUCTIONAL LEADERSHIP

Practicals are not just supplementary activities; they are a strategic tool for instructional leaders to drive quality education. The feedback provided by practical reports enables them to support teacher' professional development through organizing workshops,manage instructional resources and Creation of conducive learning environment

Instructional leadership is a crucial role for school leaders (principals, department heads, and coordinators). Instructional leaders focus on improving teaching and learning outcomes(Tsakeni, 2018). It involves guiding, supporting, and managing teachers and students towards achieving academic goals.

3.10. PRACTICAL WORK AS A REPORTING TOOL

Practicals are also used as reporting tools in both Science and Mathematics education. Practicals can function effectively as reporting tools by providing structured evidence of student learning, progress, and competency over time to the stakeholders.Practicals allowcommunication of evidence based reports by teachers to educational authorities and other stakeholders. This includes information which provides evidence of compliance with syllabus standards and reports on skills-based outcomes to prospective employers and partners.The individual student's achievements are documented throughpractical reports, logs,practical checklists, or portfolios which can be physical or digital,videos. These records serve as concrete proof of what students can do, not just what they know. This makes practicals a valuable tool for communicating learning outcomes to educators, parents, institutions, and accreditation bodies.They allow transparent reporting as they make outcomes visible. Practicals also allow reporting on both psychomotor and cognitive domains. The use of practicals as reporting tools strengthens accountability and makes assessment more meaningful. They go beyond grades to provide a rich, detailed narrative of student learning and skill development, suitable for both internal and external reporting purposes.

3.11. PRACTICAL WORK AS A TOOL FOR UNDERSTANDING THE LAWS OF NATURE.

Practical activities in Science and Mathematics education are being used to enhance understanding of the laws of nature. Through engaging in practical activities in Science and Mathematics, students would recognised and appreciate the some of the effects and impact of the laws of naturenot in only in their subjects concepts but also in their physical and artificial environments. Empirical work involved in practical work enables the learner through experiences of natural phenomena, to develop insight and understanding of the experiences and the laws of nature.Students gain this understanding when they interpret practicalwork and relate the interpretationsto natural phenomena. The suggestion is that students start without understanding of a theory, principle orconcept; they then collect data from experiences and from their interpretation of thedata, an understanding of the experienced phenomena develops.

3.12. PRACTICAL WORK AS A TOOL FOR PRACTISINGSCIENTIFIC AND MATHEMATICS SKILLS.

Practical activities are used as important tools that provide students with opportunity for practicing Scientific and mathematics skills. The hand-on involved in practicals allows practicing of some skills technical proficiency. Woolnough (1983)considers that practicals are best suited for the development and practice of specific skills through exercises.Practicals serve as essential practicing tools by bridging the gap between theoretical knowledge and real-world application. While theory provides the foundational understanding, practical exercises allow learners to apply concepts in tangible situations, enhancing comprehension, retention, and problem-solving skills.Practical sessions enable students to experiment, observe outcomes, and adapt their understanding based on real experiences. Moreover, practicals enable students to practice soft skills such as teamwork, communication, and time management, which are crucial for success in professional environments. By turning abstract ideas into observable actions, practicals act as powerful tools for active learning and skill mastery.

3.13. PRACTICAL WORK AS A TOOL FORCONSOLIDATION OF THEORETICALLY PRESENTED LEARNT SKILLS

Practical activities promotes the development of scientific and Mathematical skills and reinforces theoreticalknowledge(Evagorou, Erduran, & Mäntylä, 2015). Practical work allows students to re-engage with science learning and complements their core scientific and computing skills.This also enhances theoretical understandings.Practical work providesstudents withhands on experiences that bring to life theoretical concepts. That's good quality practical work helps develop students' understanding of scientific processes and concepts (Jakeways, 1986).By actively engaging with experiments and investigations, students gain a deeper and more lasting understanding of scientific concepts.

3.14. PRACTICAL WORK AS A TOOL FORADDRESSING MISCONCEPTIONS AMONG STUDENTS

Practicals are also used to challenge and address misconceptions among the students.Practical work can help students identify and correct misconceptions about scientific ideas, fostering a more accurate and comprehensive understanding(Lazarowitz & Baird, 1994). The information for the identification of misconceptions is obtained from students' written practical reports, portfolios and also through observing hem while engaged in practical activities.

3.15. PRACTICAL WORK AS A TOOL FORBUILDING PRACTICAL SKILLS.

Practical work in Science and Mathematics education creates opportunity for students acquire important skills. These skills include those required for research and also for carrying out experiments like using specialist equipment to take measurements, handling andmanipulating equipment with confidence and fluency, recognizing hazards and planning how to minimize risk. Students learn to collect, record, analyze, and interpret data which are essential skills for scientific investigation.Practicalactivities alsoallow students to master valuable skills

3.16.PRACTICALS AS TOOLS FOR INCULCATING SKILLS REQUIRED FOR FURTHER STUDY AND JOBS IN SCIENCE AND MATHEMATICS FIELDS

Practical work plays an important role in educating andupbringing of future specialists for individual sectors of the nationaleconomy (Tsakeni, 2018). In the Zimbabwe Heritage based Curriculum practicals are required to inculcate in Science and Mathematics students concepts, skills and attitudes necessary in preparing them for studies which are even beyond the high school level. Heritage Based Curriculum (HBC) aims to align education with national goals scientific and technological skills development and preparation of students for both academic and vocational pathways (MoPSE), 2024).The students would master the manipulative skills required for further study or jobs in Science and Mathematics fields. These skills enable students to be creative and innovative in industries and society and promote the application of

Science and Mathematics in industrial processes for value creation, addition and beneficiation of natural resources. Practicals remain paramount in inspiring students to pursue further studies in science and Mathematics. Practical work transform the student population into a human resource with the skills and competencies required for the world of work(Perer, 2019)

3.17. PRACTICALWORK AS A TOOL FORPROMOTING STUDENT ENGAGEMENT

Student engagement in the learning Science and Mathematics is about how much Attention,curiosity, interest, optimism, and passion students show when they arelearning or being taught science and Mathematics(McKeithan, Rivera, Mann, & Mann, 2021). Engagement involves a deep investment inlearning activities, leading to better comprehension and retention ofinformation(Ahmad, Razali, & Azhari, 2024). This engagement appears in three dimensions: behavioral, emotional, andcognitive. Behavioral engagement includes students participating inacademic, social, or extracurricular activities. Emotional engagement involveshow students feel in the classroom, like whether they are interested, bored,or anxious. Cognitive engagement is about how much effort students put intolearning, including their willingness to tackle complex ideas and master.Engaging is closely linked to academic success. Engaged students are morelikely to get higher grades and retain information better than those who arenot engaged (Dunn & Kennedy, 2019). Students who are actively engaged intheir learning tend to achieve higher grades and perform better onassessments. This is because engagement involves a deep investment inlearning activities, leading to better comprehension and retention ofinformation. Additionally, engagement improves student satisfaction with their learningexperience, which reduces dropout rates (Shiao et al., 2023).

3.18. PRACTICAL WORK AS A TOOL FOR MATIVATING STUDENTS

Practical activities are used to create and sustain interest of students in the learning of Science and Mathematics as indicated in the heritage based curriculum (MoPSE, 2024). Studies haveshown that students who engage in practical activities exhibit greater motivation toward science and Mathematicsand producebetter academic achievement.According to(Hodson, 1991) practical work can motivate students, stimulate their interest in learning some Science and Mathematics knowledge(Shana & Abulibdeh, 2020).Practical work has been able to promote students' positive attitudes and enhance motivation for effective learning in science and Mathematics as described by(Okam & Zakari, 2017).The hands-on activities associated with practical work spark curiosity and encourage students to ask questions.The sense of achievement felt by students when they get results of their experiments also motivates them. Practical activities often place students in semi-autonomous roles where they must plan, execute, and assess their own work. This fosters self-reliance and reflective thinking among the students. Teachers benefit from the dynamic and engaging nature of practical work, which can reignite their passion for teaching and support continuous professional growth.

3.19. PRACTICALS AS TOOLS FOR INTEGRATING THEORETICAL KNOWLEDGE IN REAL-LIFE EXPERIENCES

Practical work allow students to apply theoretical knowledge inclusive of basic principles of Science and Mathematics in real-life experiences and enhance their understanding of key concepts as indicated in the heritage based curriculum document((MoPSE), 2024).The changing of theories into real-life application make phenomena more real and beneficial to the society(Millar, 2010) .Practicals make abstract theories more tangible. This bridges the gap between conceptual knowledge and real-world relevance, helping students appreciate how ideas work in the community of practice.

Many teachers still follow traditional practices such as direct lecturing, strict use of textbook as the only reference, and rarely extend their teaching to make it relevant to real-life situations (Shana & Abulibdeh, 2020). Moreover, laboratory andpractical classes combine theory and practice, demonstrating the transition fromaccumulated theoretical knowledge to practical skills and their application tosolving applied problems(Tsakeni, 2018).This improve the meaning and relevance of science to learners as they integrate knowledge from their communities with school science and mathematics.

3.20. PRACTICALS AS TOOLS FOR WIDENING STUDENTS WAYS OF THINKING.

Practicals in their different forms are also used to develop different ways of thinking among the learners. Logical and reasoning method of thought can be promoted among students by exposing them to a series of different practical work(Shana & Abulibdeh, 2020).This effectively expands students' cognitive horizons.Practical tasks often have multiple solutions or methods, encouraging students to think creatively and explore alternatives. Practical work forces students to observe, hypothesize, test, and analyze and question assumptions and make data-driven decisions.

When students participate in practical activities, they are mentally, visually, and physically involved in the learning process, whichenhances cognitive performance and promotes independent reasoning(Schwichow, Zimmerman, Croker, & Härtig, 2016).

3.21. PRACTICALS AS A WAY OF FOSTERING IMPORTANTATTITUDES IN STUDENTS

Practical work is used as a toolfor fosteringimportant scientific social and interpersonal attitudes in students such as open mindedness, objectivity, and willingness to suspend judgment, and responsible stewardship of natural resources and cultural heritage. This role is also acknowledged by MoPSE (2024). Practical workwhether in science laboratories, technical workshops, field studies, or virtual and digital platforms involves not only the teaching of content knowledge and skills but it also shapes students' values , attitudes, approaches to learning and life and also help them develop traits essential not just for academic success but for lifelong learning and to be responsible citizens. Many practical activities involve pair or group work which encourages collaboration, communication, Perseverance and Patience the ability to share ideas and perspectives as well as mutual respect(Millar, 2010). These experiences foster social and interpersonal attitudes that are valuable in all areas of life. Hands on activities associated with practicals evoke curiosity and technological skills.When students manipulate materials or test hypotheses themselves, they begin to ask deeper questions, explore alternatives, and seek understanding beyond rote learning. Perseverance and Patience are also other virtues that students acquire as not every experiment or task works the first time. Practical work teaches students to handle failure, troubleshoot, and persist in the face of setbacks.

3.22. PRACTICALS AS TOOLS FOR STEM COMPETITIONS

Ppracticals are also used as tasks in Competitions involves hands-on tasks or experiments where participants actively apply knowledge and skills to solve problems or complete specific activities in a given time under set rules and conditions. Competitions using practicals have been witnessed in Science Olympiads which focused on experiments and data analysis, Robotics Competitions which focuses on building and programming robots.

In these competitions participants are judged on the basis of their ability to apply concepts in real situations. Competitors are also judged on their ability to think critically, make decisions quickly, and find solutions under time constraints, simulating real-life challenges.

3.23 PRACTICALS AS TOOLS FOR ADVANCING LEARNERS TO FLUENCY IN SCIENCE AND MATHEMATICS.

Practical workalso play an in important role of advancing the literacy and fluency of students in Science and Mathematics.Fluency in science means having a deep, flexible, and confident understanding of scientific concepts, skills, and processes so much so that a learner can easily apply them to explain phenomena, solve problems, and engage in scientific thinking without hesitation. It include Conceptual Understanding which means

Knowing key scientific ideas clearly and being able to connect them to other concepts. It also includes mastery of scientific language which means the ability of the student to use correct vocabulary and terminology confidently and accurately. Other measures of literacy are critical thinking and ability to explaining scientific ideas clearly, both verbally and in writing, and engaging in scientific discussions.The adoption of scientific literacy as the rationale, or main goal for scienceeducation, considered essential for all students, was reported by (Bybee, 1997).

3.24.PRACTICALS AS TOOLS IN UNDESTANDING THE NATURE OF SCIENCE AND MATHEMATICS

Practical work is also done to promote understanding of the nature of scientific enterprise. That is too understand the nature of scientific knowledge, the methods used to generate and test the knowledge claims(Millar, 2010). Through practical work students can understand that scientific knowledge is tentative, evolving, and based on evidence. When doing practical work students are expected to act like a scientist and follow scientific processes (Sotiriou, Bybee, & Bogner, 2017). This exposes them to processes used by scientists and mathematicians to investigate and discover new knowledge.This would make studentsunderstand the nature of sciencethrough replicating the actions of scientists. The scientific method is a systematic approach to investigating phenomena, acquiring new knowledge, or correcting previous knowledge. It involves observation, question, hypothesis, experimentation, data collection, analysis, conclusion and communication. Practicals help in every step of this method by providing hands-on experience.

3.25. PRACTICALS AS TOOLS USED TO ACQUIRE KNOWLEDGE IN STEM FIELDS

Practicals are used as means through which students acquire knowledge in both Science and Mathematics. There are different sources of both Scientific and Mathematical knowledge. These sources include life experiences, social customs and traditions, authority, deductive and inductive reasoning, social inquiry method and scientific method. Practical work involves some scientific and mathematical methods both of which create knowledge. The Heritage Based Curriculum in Zimbabwe indicates that practical work in Science and Mathematics Education creates opportunities for students to acquire both Scientific and Mathematics knowledge inclusive of basic principles in Science and Mathematics. This knowledge includes that about physical phenomena, facts, laws, definitions and concepts of Science and Mathematics.It also include about how to apply procedures involved in Science and Mathematics.

3.26.PRACTICALS AS TOOLS STIMULATING INTREST AND ENJOYMENT

Practicals work is used as a tool for stimulating interest and enjoyment of the science and mathematics by the students (Hodson, 1998). The HBC emphasizes that the methodology of teaching Science and Mathematics should provide students with practical experiences so that they can appreciate Science and Mathematics as active and exciting study.Millar (2010)confirms that practicals are very Exciting Activities. Practical activities in education transform learning from passive listening into an active, hands-on experience. This makes learning exciting and engaging for students in several ways inclusive of Students enjoy the thrill of discovery when they observe phenomena or create something themselves. This natural curiosity makes practicals fun and memorable. Sparkingenthusiasm and motivation as a result of applying theory to real-world situations Students enjoy the thrill of discovery and exploration when they observe phenomena or create something themselves. This natural curiosity makes practicals fun and memorable. Seeing immediate results from their actions whether an experiment works or a machine functionsgives students instant satisfaction and a sense of accomplishment. When students work in groups during practicals, this often makes learning social and lively adding to the excitement as students share ideas and solve problems together.

3.27. PRACTICALS AS A MEANS OF INCULCATING CRITICAL THING SKILLS

Practical work is used as a tool for promoting Critical thinking. Scriven and Paul (1987) defines critical thinking as "the intellectually disciplined process of actively and skilfully conceptualizing, applying, analysing, synthesizing, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action. Practical work promotes logical reasoning and meaningful methods of thought and other scientific and Mathematical habits of thought(Millar, 2010).Practical work provides opportunity for students to actively engage with concepts leading to deeper understanding and the ability to observe, collect data, analyse, evaluate and draw conclusions through experiments and investigations. These are basicallythe majorelements of critical thinking. Practical work and critical thinking are inter-twined, as practical work provides hands –on context for developing and applying critical thinking.Exposing students to a series of practical activities helps students to develop critical thinking skills like problem –solving, reasoning and evaluation

3.28. RESPONSE TO GLOBAL TRENDS.

Practicals are being done in Science and Mathematics education in schools in Zimbabwe as evidence of the education system that it is responsive to global trends in STEM education. Generally education systems have to follow global trends so that their graduates remain marketable on the global job markets. The global trend is that hands-on activities including practicals should be included in the teaching of STEM subjects (Maass & Engeln, 2019). Practical work facilitates student learning through engaging in impactful practical work. Additionally, the impact of science practical work on teachers includes improved subject knowledge, enhanced teaching skills, and increased professional satisfaction.

Some educationists criticise the use of practicals in Science and Mathematics education. They state some disadvantages of laboratory-based teaching as being an inefficient teaching method and cannot represent scientific inquiry properly, rather this should be taught through direct lecturing(Millar, 2004). Also, Hodson (1991) claimed that practical work may be applied in a way where students only follow the instructions given by the teacher and which means they do not need to use creativity or cognitive thinking to process the information. Thus practical work is a waste of time, confusing and counter-productive(Hodson, 1991).On the other hand, Sotiriou et al. (2017) mentioned that traditional lab work focuses solely on scientific terminology and allows students to see only what is happening during experiments; in addition, students may follow instructions written in the lab manual step by step which will not give students the chance for creativity and cannot develop their cognitive skills. If students simply follow the lab manual during experiments without connecting it to real life, then the methods will be of no value. According to Madhuri, Kantamreddi, and Prakash Goteti (2012) “the most important negation of cookbook style laboratory is it doesn't help students translate scientific outcomes into meaningful learning.”Conventional laboratory work or activities fail to engage students in discussions and do not promote the development of the skills needed to understand chemistry effectively(Schweingruber, Hilton, & Singer, 2006).

Traditionally practical work in science education involves learners following a highly structured, step-by-step approach, where teachers dominate and control the sequence of activities, while learners play a passive role (Zion & Sadeh, 2007; Wellington, 2002; Zion & Sadeh, 2007). The step-by-step procedure is laid down by the teacher or the recommended textbooks. Students' discussion during the laboratory work is mainly cantered on the procedures needed to carry out the experiment or how to manage lab equipment (Russell & Weaver, 2011).

Conclusion

The chapter revealed the roles played by practical work in Science and Mathematics education and what teachers intent to achieve when they engage their students in practical activities. The roles include the practicals being used in Science and Mathematics education as: an instructional strategy, tools for achieving inclusivity, tools for promoting conceptual development, tools for determining curriculum content, tools for theory building, tools for illustrating and verifying theories and principles, tools for monitoring, evaluation and evaluation of learning and teaching processes, tools for guiding instructional leadership, tools for enhancing understanding of natural laws, tools for enhancing consolidation accommodation of theoretically presented learnt concepts and skills, tools for challenging and addressing students' misconceptions, tools for inculcating skills required for further study and jobs in the Science and Mathematics field, tools for promoting student engagement and their motivation, tools for integrating theoretical knowledge and real-life experiences, tools for widening students' ways of thinking, tools for fostering Scientific attitudes in students, tools for advancing students' fluency in Science and Mathematics concepts and skills, tools for acquiring knowledge in Science and Mathematics and fields, an area where Science and Mathematics competitions are organised, tools for stimulating interest and enjoyment in Science and Mathematics fields, tools for promoting critical thinking and also as evidence of the education system that it is responsive to global trends in Science and Mathematics education.

Given these important roles played by practical work in Science and Mathematics education, the quality quantity and breadth of practical work should be the ultimate focus of Science and Mathematics education. Consequently, science teachers should be trained based on the most recent research studies on the roles of practicals in Science and Mathematics education to amend their practices and put forth more time and effort in teaching practical work.

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Chapter 4: Assessment of practical work in science and mathematics education

1 Introduction

In science and mathematics education, learners' skills, conceptual understanding, and ability to apply knowledge in real-world scenarios are evaluated through practical experience. Under the Competency-Based Curriculum (CBC) introduced in 2015, the curriculum in Zimbabwe is centered on the learner. The emphasis of practical work in this educational system is now on developing problem-solving, critical thinking, and innovation skills. However, evaluating practical work in science and mathematics is still a complex and multifaceted process that includes considerations of education (pedagogical), infrastructure and policies.

2 The aim and nature of practical work assessment

Assessing learners' ability to apply theoretical knowledge in experimental or problem-solving contexts is the primary objective of assessing their work. The teaching of science and mathematics involves acquiring knowledge in laboratory settings, conducting experiments independently or with different methods, modeling, measurements, or problem-solving with real-life data and manipulative tools. Assessment serves both formative purposes of forming instruction and learning, as well as summative functions of measuring competence and guiding progress.

Specific practical skills, such as measurement and observation, that may be useful in future studies or employment, are taught through practical work (Wellington & Ireson, 2018; Chirikure, 2023). These skills and attributes include fostering open-mindedness (for scientific inquiry), objectivity, and willingness to suspend judgement, teaching principles of science; providing insight into scientific methods/expertise; and helping students develop critical thinking skills related specifically to science (Chirikure, 2023). The ability to manipulate a specific apparatus or equipment is considered practical skill according to Reiss et al (2012), while generic skills are not domain-specific and are crucial for employment. In Zimbabwe, practical work is incorporated into science and mathematics from Early Childhood Development (ECD) up to university level. The implementation of practical components in coursework and final assessments is mandatory at each learning level.

Assessment of practical work in science and mathematics education from a constructivist view

Learner- centred practical approaches to teaching and learning are preferred by the Zimbabwean science curricula, for example, the competence- based curriculum syllabi for Biology, Chemistry, and Physics (Ministry of Primary and Secondary Education, 2015curricula, for example, the competence- based curriculum syllabi (Ministry of Primary and Secondary Education (MOPSE), 2015; Sunzuma & Luneta, 2022). Research on learning, particularly in the areas of science and mathematics education, has been greatly influenced by the constructivist approach, as noted by Taber (2002). The main focus of this method is on how learners connect their existing knowledge structures to new information, leading to meaningful learning. The theoretical basis of constructivist teaching, as described by Hodson (2006), is that learning is based on the knowledge of students. Instead, learners are seen as people who take an active role in building knowledge.

Educators in science and mathematics often overlook the experiential, inquiry-based nature of these subjects. Taber (2002) suggests that the evaluation of practical work in science can lead learners to misinterpret science as a static collection of facts rather than an active experimental process. The rote procedures and abstract testing in mathematics can make it difficult to discern the investigative and problem-solving nature of the subject matter.

Creating assessments that are credible and reflect authentic knowledge is a significant concern in both fields. To capture the range of outcomes, conceptual or procedural in learners, constructivists suggest that effective assessment must be multifaceted. The use of valid, reliable, and process-oriented assessment methods is emphasized by Segers et al. (2003). In the past, summative testing has been a popular choice for classroom assessments. Taber (2002) contends that examination boards tend to concentrate on final examinations rather than providing comprehensive knowledge, often leading to a focus on test preparation.

On the other hand, constructivist pedagogy emphasizes formative evaluation in the context of learning (Zezekwa, 2016). Continuous feedback is valued in the assessment of learning, with the aim of developing competencies and improving one's metacognitive skills. In science and mathematics classrooms, this could entail real-time assessment through investigations, problem-solving discussions, or group tasks.

Hudson (2009) suggests that formative assessment aids students in distinguishing their learning progress and areas for improvement, leading them towards well-defined goals.

Diagnostic assessment is a crucial aspect of constructivist teaching. Teacher exposure can help students discover their past knowledge and misconceptions, especially in science and mathematics, where alternative ideas can hinder progress (Taber, 2002). Modern assessment practices must adapt to meet 21st-century learning objectives. Segers et al. (2003) advocate for reforms that involve lifelong learning and the integration of knowledge and skills into an integrated system through critical thinking. In constructivist schools, assessment methods such as portfolios, performance-based tasks, peer evaluation, and reflective journals are commonly employed. The tools offer a glimpse into the reasoning, conceptual linkages, and problem-solving skills of students. In addition to assessing content knowledge, Mintzes, Wandersee and Novak (2005) also note the need to critically evaluate the ability to apply and relate ideas across contexts.

Higher-order thinking and learning autonomy are fostered by constructivist assessment. Through it, students are tasked with being part of their own development, encouraging reflection and self-regulation. Shepard (2000) warns that the test-driven curricula can undermine these progressive practices. It is necessary to assist teachers in defending and practicing constructivist-based assessments when faced with external pressures for standardized testing.

Constructivist approach to teaching science and mathematics emphasizes practical work. According to Hodson (2006), real-life activities must accurately reflect scientific and mathematical investigation. The assessment of practical work in science and mathematics should not solely rely on lab reports or structured practical tests, but also incorporates real-time observations, checklists, and student reflections. In both science and mathematics, observation and learner explanation can be used to evaluate practical investigations such as exploring geometrical patterns or conducting measurements, or modelling real-world problems. These methods enable learners to demonstrate understanding through active participation and contextual problem-solving.

Nonetheless, constructivist beliefs are not entirely without flaws. Kirschner, Sweller, and Clark (2006) contend that the theory's pedagogical prescriptions can be problematic for learners who lack self-management or fundamental knowledge due to its accurate depiction of learning. According to Mayer (2004), constructivist learning environments may have a negative impact on students who require more structured instruction. By incorporating constructivist approaches, a balanced assessment approach can be used to meet the diverse learning needs of science and mathematics education.

Summative Assessment

In science and mathematics, summative assessment is still necessary for certifying learner achievement at the end of instructional periods, such as terms or academic years (Chauraya, 2023). Zimbabwe's standard exams are summative assessments that consist of written tests and standardized practical tests, such as the ZIMSEC Ordinary and Advanced Level tests (Chauraya, 2023). The assessments assess the ability of learners to grasp concepts and procedures under specific time constraints. Summative assessments for practical purposes may comprise of structured laboratory examinations or problem-solving tasks in which students apply scientific methods or mathematical reasoning. The use of summative assessments can establish educational standards and expectations, but it's still problematic to ensure their accuracy in reflecting students real-world skills (Zezekwa, 2016). Hands-on skills are often marginalized in schools with limited resources, especially when written formats are overemphasized. The assessment of practical skills in Zimbabwe's education system must be authentic and rigorous, balancing theoretical theory. The use of summative tools in conjunction with continuous and practical assessment contributes to a more balanced and inclusive approach.

Summative assessment, which is the primary component of constructivism, also serves as a means to evaluate learners' completed skills in science and mathematics. As a result, the evaluation of practical tasks in these subjects should encompass both experiential and final aspects, providing broader perspectives on how learners progress and comprehend their learning (Zezekwa, 2016).

Formative Assessment

Formative Assessment refers to the process of collecting, combining, and interpreting information to assist in decision-making. There are two primary types, namely formative and summative assessments. Some forms of both formative and summative assessments are now being referred to through the use of offshoots in literature. Real assessment of practical work is exemplified by the direct assessment (DAPS), as defined by Reiss, Abrahams and Sharpe (2012 as authentic assessment as defined by McMillan (2004). Authentic assessment as defined by McMillan (2004), involves requesting students to complete practical tasks that demonstrate their meaningful use of essential knowledge and skills through real-life applications. A test that is considered valid usually includes a task for students and evaluating their performance using grading (Zezekwa, 2016). This is known as performance assessment because students are evaluated during tasks, as described by Pedder (2006).

Shepard (2008) defines formative assessment as an assessment conducted during instructional instruction that aims to enhance teaching and learning, and makes adjustments to inform new learning. In William and Leahy's (2007) view, an assessment is formative in that it can be used internally or externally to improve the system' performance. Formative assessment is a process that develops information about learning and uses it to improve teaching and learning activities, as noted by Black et al. (2003).

Different forms and methods of formal assessment exist. In 2001, Bell and Cowie introduced Interactive Formative Assessment (IFA) as a concept. Classroom Formative Assessment (CFA) is a topic covered by Dufresne and Gerace (2004). Teacher-student interaction is the underlying process for Interactive Formative Assessment (IFA), as stated by Bell and Cowie (2001). Students' thinking is observed, acknowledged, and responded to by teachers in a process that prioritizes teacher-student interaction over curriculum influence. Bell and Cowie (2001) indicate that a test of this nature produces information that is infrequent as it involves the teacher's response after identifying areas where the student may require assistance. The idea is backed by Fairbrother (2008:70), who maintains that only educators can evaluate students' objectives, which are directly related to their work and should therefore be prioritized. Evaluation must provide short-term feedback to identify and address issues early in the learning process. The relevance of this lies in the impact that assessment-related information has on teaching and learning outcomes.

The CFA system is used to evaluate classroom activities. According to Dufresene and Gerace (2004), CFA enables educators who aim to gain knowledge about student comprehension in order to enhance student learning. According to Durfresene and Gerace (2004), the main aspects of CFA are the interactions between teacher and small group members, class-wide discussion, flexible teaching, feedback to students, and student self-assessment of their work and understanding. Dufresene and Gerace (2004:428) stated that the process involves presenting questions to class, collecting and storing individual students' answers, displaying their answers anonymously, recording their progress, and reporting on small groups. This point suggests that students can use this to evaluate the effectiveness of their current models of interaction and identify areas that need to be improved. CFA involves a shift in the classroom culture, shifting from focusing on answers and teaching to prioritizing students' mental process through analysis and reasoning activities. In accordance with Black and William's (2004) perspective, formative assessment is not a tool for measuring an event, but rather consists of several practices that have essentially the same effect of promoting learning. It implies that the assessment is primarily intended to offer feedback on performance in order to enhance and accelerate learning. Effective formative assessment, as argued by William and Leahy (2007:105), involves five primary strategies; establishing learning objectives and sharing performance benchmarks; encourage effective classroom discussion, questions, and learning tasks that lead to evidence of learning; provide feedback that moves learners forward; foster students' ownership of their own learning.

Formative Assessment of Practical work

Success of formative assessment of practical work depends upon forward planning, flexible timetables and good will on the part of all involved according to Fairbrother (2008). Fairbrother (2008) identifies some options on effective assessment to include two teachers in one class, small group of experiments and to increase the number of technicians among many other strategies. Teachers who are evaluating practical work tend to feel most strongly about it, particularly towards insecurity and uncertainty. The solution according to Fairbrother (2008) is to plan well, to start assessing and recording as early as possible and concentrate on and assess a limited number of objectives. If practical work is assessed in a summative way this won't give maximum benefit to the students as practical work reports assessment divorce the theoretical aspects of practical science from hands on practice despite both being integral skills. Downs (2013) argues that the evaluation of practical reports misrepresents the scientific nature and may result in a decrease in students' hands-on learning skills. A summative assessment of students' practical work skills can lead to a lack of proficiency in certain skills essential for higher education and science career advancement.

The use of formative assessment, as noted by Black and William (2004), fosters reflection and stimulates students' comprehension. Instead of comparing, the presentation emphasizes ways for a student to improve. The question is: "Where do you want to go? Provides a clear vision of what you're trying to learn. Where are you currently?" (Self-reflection). How can students be directed towards that goal? (Studentship) Shepard (2008, 143)

According to Dufresne and Gerace (2004), formative assessment seeks to monitor and influence the growth of students' thinking process, inquiry skills, and attitudes towards science and learning behaviours. To accomplish this, it is essential to incorporate continuous assessment forms into daily learning activities. By utilizing classroom assessment regularly, students can improve their performance in math and science by analyzing evidence about their learning and tailoring instruction accordingly, as observed by William and Thompson (2007). Literature has consistently emphasized the importance of formative assessment in monitoring student learning and practical work skills.

Conceptualising assessment of practical work in science and mathematics education

As recommended in the Curriculum Framework, practical work contributes significantly to learners' final scores, promoting applied learning and skill development across all learning levels.

> *The framework envisages continuous, practical, and summative assessment regimes to measure theoretical and applied learning. The application of all these tools is essential for achieving satisfactory outcomes. For practical learning areas, continuous assessment contributes a greater percentage towards the learner's final score even at the secondary school level (Ministry of Primary and Secondary Education, n.d., p. 67).*

The framework's use of continuous, practical, and summative assessment regimes demonstrates a comprehensive approach to measuring theoretical understanding as well as applied competencies in science and mathematics education. The framework recognizes that learning is not solely focused on memorizing content, but also includes demonstrating conceptual awareness, procedural abilities, and the ability to apply knowledge in practical situations by merging various assessment methods. The focus on practical learning areas through continuous assessment is highly valued, especially at the secondary level. Through hands-on activities, it maintains a continuous learning process and helps students improve in their abilities over time. This is in line with constructivist and socio-cultural approaches, which advocate formative, process oriented evaluation for learner development (not individual testing).

Also, the inclusion of greater proportions in continuous appraisal reinforces the importance of persistent effort, practical application, and incremental improvement. Instead of rote learning, it promotes the ownership of one's own learning. Yet successful application requires strong teacher training and adequate resources to ensure fairness in comparison with regular evaluation. Overall, this comprehensive system has been defined by the Ministry of Primary and Secondary Education. Science and mathematics provide a solid foundation for authentic assessment practices that better capture learner development.

It is important to capture the learners' progress in science and mathematics through continuous assessment. Compensation-based education in the Zimbabwean curriculum places greater emphasis on continuous assessment, which is of utmost importance. It allows pupils to develop their practical skills over time, rather than relying on high-stakes exams. In areas such as mathematics, students can receive weekly assessment through problem-solving challenges, projects, and investigations. Scientific continuous assessments in science often involve laboratory journals, practical reports, and performance in hands-on activities (Chirikure, 2023). These assessments enable teachers to identify misunderstandings and provide appropriate guidance. Importantly, it fosters sustained effort and encourages the application of theoretical ideas to practical applications. Continuous assessment aids in the deeper engagement of content, promoting critical thinking and experimentation, which are essential for scientific and mathematical inquiry (Chirikure, 2023). Consistent assessment provides a more comprehensive and precise depiction of student achievement.

Science and mathematics education rely on practical assessment, which assesses learners' readiness to apply knowledge through experimentation, observation, and problem-solving (Chirikure, 2023). Zimbabwean science involves a variety of practical tasks, such as experiments, diagramming, quantity estimation, and data interpretation. Mathematics may involve the creation of geometrical models, solving practical problems, or utilizing mathematical tools like compasses and protractors. During the practical assessment, students can interact with scientific and mathematical processes in real-time scenarios, which reinforces their theory through practical application. Practical assessment is essential to ensure that learners are involved in their education, given the emphasis on learner-centred and inquiry-based learning within the Curriculum Framework (Chirikure, 2023). It likewise conforms to the objectives of producing students who possess technical expertise and are prepared for careers in STEM. The implementation of equitable measures in Zimbabwe requires addressing resource disparities in schools to ensure that all students are capable of performing well on practical tasks. In STEM education, practical assessment is crucial to verifying knowledge through experimentation.

Direct Observation

The use of direct observation is a crucial formative assessment strategy in Zimbabwean science and mathematics classrooms when teaching practical work. Teachers monitor students in real-time while they are engaged in activities such as experiments, mathematical problems, or modeling. Through this method, teachers can assess not just the accuracy of outcomes but also process skills such as the appropriate use of scientific equipment, mathematical procedures, teamwork, and inquiry behaviours. The assessment of skills like measuring, heating and titration, as well as handling specimens, is particularly important in the field of science. Mathematicians may employ manipulative devices like graph boards or geometric instruments. Checklists or anecdotal records are commonly used by educators to document observable behaviors and provide guidance for providing feedback and intervention. In Zimbabwe, the use of this approach is in line with the curriculum's emphasis on continuous assessment and can be advantageous for students with diverse abilities, as it allows for the recognition of practical skills despite differences in theoretical understanding.

Performance Tasks

Students in science and mathematics classrooms in Zimbabwe are required to complete structured practical tasks, which are overseen by a teacher. The assignments could consist of performing customary experiments, resolving mathematical problems, creating visual representations, or examining data sets. As an illustration, a science performance task may require students to investigate the reaction of acids and bases, while in math, they can use real objects to calculate areas or measure angles. Rubrics are utilized by educators to measure standards such as accuracy, logical process, correct application of formulas, and ability to interpret results. The task serves as a link between theory and practice by motivating students to implement their learning in real-world scenarios. In situations where learners may not have frequent access to laboratories or advanced resources, performance tasks are crucial as they foster creativity and the use of improvised materials. They also promote Zimbabwe's Curriculum Framework, which emphasizes the use of hands-on, competency-based assessment methods to enhance application of scientific and mathematical concepts.

Portfolios and Journals

Portfolios and learning journals serve as a means for science and mathematics learners in Zimbabwe to showcase their ongoing practical work. Students in science may present their experiment with records of experiments, diagrams, data tables, and reflections on processes and outcomes. Mathematics portfolios may include problem-solving steps, graphical interpretations, and personal approaches to solving challenging problems. Learners can use journals to share their learning, challenges they encountered, and strategies for overcoming them. Self-awareness is elevated and conceptual understanding enhanced. Portfolios are examined by educators to evaluate the learners' development over time, their consistent use of methods, and their capacity to express ideas. Especially in contexts with limited resources for the regular formal practical testing, portfolios can be an invaluable resource for continuous assessment. Zimbabwe's curriculum encourages pedagogies that prioritize learner involvement, critical thinking, and the application of scientific and mathematical knowledge in local contexts. These strategies are supported by their respective institutions within schools.

Project-Based Assessments

Project-based assessments are used in science and mathematics education in Zimbabwe, which enable learners to undertake extensive, often interdisciplinary investigations. Science can encompass environmental studies, which may involve testing the local water supply or assessing soil fertility. Mathematicians could participate in gathering and analyzing data from a market survey or rainfall measurements. The main focus of these projects is on research, data analysis, and presentation of findings. The connection between classroom concepts and local community problems is key to making learning more meaningful. These projects usually end in presentations or written reports, and are assessed against criteria relating to methodology (planning), design/methodology ("use of concepts," innovation) and communication. This method supports the Curriculum Framework's emphasis on problem-based learning and promotes innovation and entrepreneurship, particularly among learners who are concerned with social, economic, or environmental issues in their communities. Additionally, Key skills for Zimbabwe's economy that is based on knowledge can be developed through project-based assessments that emphasize collaboration, critical thinking, and sustained engagement.

Written Reports and Lab Write-ups

Science and mathematics education in Zimbabwe typically evaluates practical work through written reports and lab write-ups. By using these documents, learners can articulate the complete process of a practical task, including the hypothesis or problem statement, data collection methods, and analysis and conclusions. In science, students may report on chemical reactions or biological experiments. They may describe in mathematics how to derive a formula or use data to solve 'real world' problems. This assessment not only enhances pupils' communication skills in scientific and mathematical terms but also provides evidence of conceptual understanding for teachers.. It also promotes logical thinking and precision, both core competencies in STEM. Additionally, it provides training in academic writing and records keeping that are important for future studies and careers. Such assessments are valued in Zimbabwe's curriculum because they combine theoretical application with reflective analysis, allowing teachers to assess process and product within the material as learners build up their knowledge.

Peer and Self-Assessment

Peer and self-assessment on practices are gaining popularity in Zimbabwean classrooms as a means of improving practical work in science and mathematics. Science learners may use basic rubrics, share comments on accuracy, technique, or collaborate to evaluate their peers' lab performance. Students in mathematics may observe each other's techniques for problem-solving or drawing graphs. During self-assessment students analyze their strengths, areas of difficulty and progress in doing tasks. The use of these techniques promotes metacognitive awareness, accountability, and collaborative learning. Significantly, these also develop the capacity for students to set objectives and goals independently, track their own progress and adjust strategies. The feedback from peers fosters interpersonal and communication skills, which are crucial for collaborative scientific research or mathematical problem-solving. These assessments align with Zimbabwe's competency-based curriculum, promoting the autonomy of learning for students and encouraging greater engagement. Teachers act as a guide, teaching pupils to evaluate with fair and constructive criticism without losing the focus on learning.

The proposed model (see figure 4.1) of practical assessment in science and mathematics education is grounded in the following the principles.

Competency-Based Learning

It emphasizes demonstration of observable skills and knowledge in real-life applications (experiments, solving problems or investigating etc.). Students are evaluated on their aptitude by incorporating their knowledge; they are in line with Zimbabwe's growing trend of measuring performance and competence more than memorizing information by heart. The assessment system prioritizes practical abilities such as precise measurement, data analysis and critical thinking to ensure learners achieve specific learning outcomes at varying levels of competence.

Authentic and Continuous Assessment

The model employs various tools such as performance tasks, portfolio's, journals and project-based assessments to emulate real-life scientific practices and math. It values the continuous monitoring of progress over time through teacher observations, formative feedback, and structured reflections. According to the MoPSE (2015), this continuous process fosters deeper learning and provides a comprehensive view of learners' capabilities.

Learner-Centred Pedagogy

This model promotes the autonomy of learners through self-assertion and peer comparison. This promotes metacognitive engagement, whereby students evaluate their own and others' performances. Students are encouraged to actively participate in the construction of knowledge through inquiry, experimentation, and collaboration, as per the model's constructivist and sociocultural learning perspectives. This approach is emphasized in this work.

Contextual Relevance to Zimbabwean Communities

Assessment is determined by local contexts, utilizing available resources, community challenges, and indigenous knowledge systems. Scholars grasp the significance of studying water quality in local rivers and exploring math in traditional crafts, as they relate it to their daily routines. Additionally, contextual grounding also helps learners to become more culturally responsive and their environment more conducive.

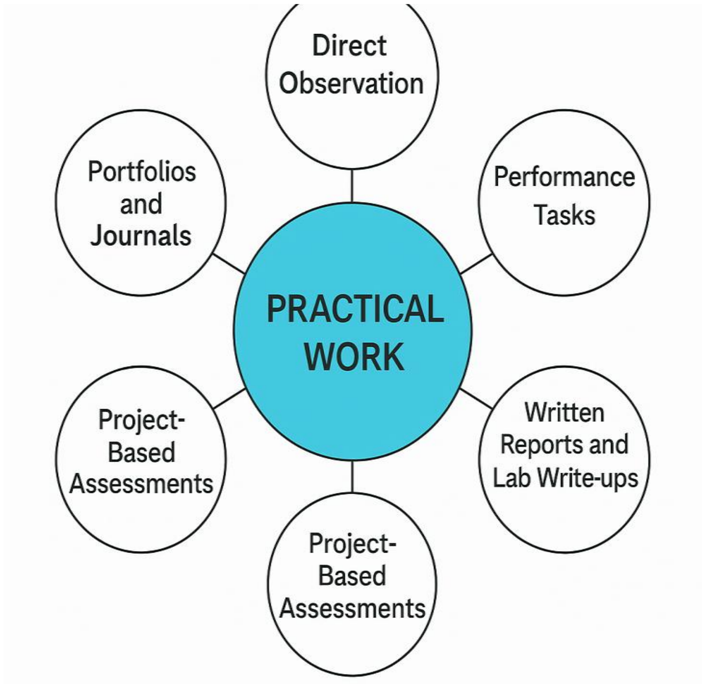

Fig 4.1 Practical work assessment model

A comprehensive and well-organized approach to assessing practical work in science and mathematics is represented by the proposed model. This is theoretically and practically practical, in line with the goals of Zimbabwe's updated curriculum as well as wider educational reforms. By placing practical work at the heart of the model, learners are repositioned to be active participants in their own learning process, rather than passive recipients of knowledge.

One of the strengths of this model is its ability to include a variety of assessment strategies: direct observation, performance tasks, portfolios, projects; written reports and peer/self-assessment. This kind provides a comprehensive evaluation of learners' capabilities, accommodating diverse learning approaches and providing more extensive evidence of learning than traditional assessments. Additionally,

Additionally, the model fosters relevance and engagement by connecting assessment tasks to community-based issues and indigenous knowledge, enabling learners to appreciate the value and potential of science and mathematics in their daily lives. The model fosters the use of learner-centred pedagogy and formative feedback loops, which are crucial for creating self-regulated, reflective learners. By emphasizing practical applications, it advances competency-based learning and equips learners for both national assessments and lifelong learning.

In spite of this, successful implementation depend on teacher training, adequate resources (especially in rural schools), and systemic support to sustain quality and consistency across schools. The model may become a checklist instead of transforming as if they were the only thing in it. The model is progressive, inclusive, and contextually sound, making it an ideal platform for improving science (and most importantly, teaching) mathematics through meaningful practical assessment in Zimbabwe.

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Chapter 5: Science and Mathematics education Practical work implementation barriers

1 Introduction

Effective science and mathematics education requires engaging, hands-on work that promotes conceptual understanding, critical thinking, and problem-solving. All types of activities should be regarded as integral components. Zimbabwe's national curriculum explicitly emphasizes the integration of practical activities to ensure learners develop theoretical knowledge as well as practical competencies. Even with policy endorsement and pedagogical recognition, the implementation of practical work in schools still faces many obstacles.

The chapter discusses the systemic, institutional, and contextual factors that impede the effective execution of practical work in science and mathematics classrooms throughout Zimbabwe. These obstacles range from underdeveloped infrastructure, limited resources and poorly qualified teachers, large class sizes, and rigid assessment systems. The inequalities in access to meaningful hands-on learning opportunities between urban and rural schools are exacerbated by socio-economic disparities. The chapters aim to provide insights that can aid in policy reforms, teacher professional development, and practical work implementation strategies by examining these barriers. It is crucial to acknowledge these challenges in order to promote a more inclusive, competency-based and contextually relevant science and mathematics education system in Zimbabwe.

2. Barriers to practical work implementation

Teacher Concerns and Professional Content Knowledge

Teacher's professional competence and confidence are crucial to the successful execution of practical work in science and mathematics education in Zimbabwe. Practical activities are designed, delivered and evaluated by teachers in a central manner. Even though they are rural and often under-resourced, educators in Zimbabwean schools express significant apprehensions about their own content knowledge or the school's ability to teach effectively through hands-on learning. The challenges presented are formidable in integrating practical work meaningfully into everyday teaching and learning.

Teachers must take into account various concerns related to promoting practical work, such as managing tasks and maximising practical working relationships with students. They also consider using effective laboratory techniques to collaborate with other teachers and refine tasks while considering student skills development. On the flip side, there is a worry that instructors could be indoctrinated by 'magical rhetoric' that sees practical work as universal "solutions" for learning problems in science. This is especially concerning, as teachers are frequently found to be unable to properly guide students in practical tasks. Despite the identified inadequacies, teacher education and disciplinary programs have been prioritizing practical work over nuclear clarification on the meanings of words/ concepts during performance. The importance of pedagogical competence in effective classroom communication is not adequately recognized in the initial training and professional development programs of science teachers, as evidenced by the frequency and quality of practical work (Oliveira & Bonito, 2023). This perspective may be supported by other sources. Also, cultural concerns concern the level of preparedness among students and teachers in their zone of proximal development to support progress towards research learning practices. Practical work, which involves the exploration and interpretation of relationships, often includes inadequate data analysis. However, enhancing data analytics proficiency is not the primary objective of practical work; ineffective data analysts limit learning outcomes. A serious mismatch between the intended curriculum and the effective implementation of practical work in science is one of the concerns within this category. A misreading of a poorly designed global curriculum by teachers could lead to this situation, necessitating the development of more effective curriculum designs. While the ideals of curriculum developers may be noble, without a well-defined and formal curriculum, interpretations will not be correct, leading to misreading the information presented above (Phaeton & Stears, 2017). A constructivist perspective (S52) proposes that a more effective curriculum should be created by students, rather than solely focused on the teacher (Oliveira & Bonito, 2023).

Inadequate Pre-service Preparation

A significant problem is the insufficient training provided to teachers before deployment to schools (Mufanechiya & Makgalwa, 2024). Several teacher education programs in Zimbabwe emphasize theory rather than practicals (Mutseekwa, 2021; Mufanechiya & Makgalwa, 2024). Therefore, it is common for student teachers to not receive the practical knowledge required to conduct science or mathematics experiments, adapt to new concepts, and evaluate them with confidence upon graduation (Kadziya & Ndebele, 2020). In physics, chemistry, and advanced mathematics there is an obvious gap where the laboratory-based or applied activities are complex and require specialist knowledge (Mufanechiya & Makgalwa, 2024).

The ability of a teacher to explain tasks clearly and accurately during training is often due to their limited exposure, experience, and knowledge of teaching techniques (Kadziya & Ndebele, 2020). In addition, many teacher education institutions do not have state-of-the-art laboratories or a sufficient raw material, which is a reflection of the resource deficiency in most schools in Zimbabwe (Mutseekwa, 2021; Mufanechiya & Makgalwa, 2024). As a result, educators enter the field without the necessary skills to handle the logistical and pedagogical demands of practical tasks.

Limited In-service Professional Development

A significant component of teacher professional development is the in-service enhancement of content expertise and pedagogical proficiency. Unfortunately, there are limited opportunities for continuing professional development (CPD) in practical work in Zimbabwe (Mufanechiya & Makgalwa, 2024). Practical skills, safety measures, inquiry-based learning, or differentiated instruction for practical tasks are not commonly used in CPD workshops, which tend to be too theoretical (Mutseekwa, 2021). In addition, there is a discrepancy in the distribution of professional development programs, with urban teachers being more likely to receive these opportunities than rural teachers.

Content Knowledge Gaps

Deep understanding of subject content is essential for facilitating practical work (Kadziya & Ndebele, 2020). It is important for teachers to not only grasp concepts but also anticipate common student misconceptions, design assignments that stimulate conceptual thinking, and guide learners through data interpretation/logical reasoning/reflexion. Science and mathematics involves comprehending scientific procedures like hypothesis testing, control variables, and data analysis. In mathematics, this can mean applying mathematical models to real problems, exploring the relationship between shapes and motion in space or time, or using manipulatives for number sense development (Magwende & Maharaj, 2019). Yet many studies and school-based reports in Zimbabwe have shown widespread lack of knowledge about content among science and mathematics teachers. Specialized knowledge is necessary, which becomes more evident in secondary school level courses. To illustrate, a teacher who lacks confidence in calculus or chemical reactions may opt for rote teaching and disregard the relevant practical tasks. This hinders students' capacity to engage in meaningful inquiry, experimentation, and the genuine teaching of concepts.

Fear of Classroom Management Issues

A further issue for teachers is the management of the classroom environment in practical scenarios. The nature of practical lessons suggests that they are less structured and more focused on the learner than lecture presentations. Classrooms in Zimbabwe, where there are few students and many have high student-teacher ratios, can be chaotic with hands-on learning; some teachers fear safety and disciplinary issues. Science labs and mathematics classes that require movement and group interaction are particularly affected by this issue, which involves the use of hazardous chemicals or equipment (Mandina, 2017).

'Chall and talk' is the preferred method of teaching in schools where practical classroom management is not adequately trained, and teachers view practical work as a risk rather than an opportunity (Mandina, 2017). Moreover, studentss might avoid attending practical sessions due to concerns about potential accidents and financial limitations. Teachers' capacity and eagerness to incorporate practical instruction into their daily routine is curtailed by a climate of caution.

Assessment Anxiety and Accountability Pressures

In Zimbabwe's assessment culture, high-profile summative examinations are highly regarded (Maharajh & Musekiwa, 2021). In general, educators prioritize content coverage over practical knowledge or deep comprehension. There is a worry that time spent on practical work may hinder the completion of syllabus, especially in Grade 7, Form 4, and Upper 6 subjects. In practice, the assessment of practical work is uncertain due to the lack of clear guidelines, standardized tools, and moderation systems that ensure it meets all relevant standards for continuous assessment mandates (Maharajh & Musekiwa, 2021).

Educators are apprehensive about how their work will be evaluated in external assessments. The lack of formal assessment for practical or investigative work in mathematics makes it a rare topic in teaching. Nationally recognized performance-based assessments or rubrics are not easily attainable for some teachers. A lack of assessment literacy leads to a greater reluctance to participate in practical instruction.

Curriculum Ambiguities and Misalignment

Teacher problems frequently arise from unclear curriculum statements or vague guidance on practical expectations (Mufanechiya & Makgalwa, 2024). Zimbabwe's curriculum is based on competency, but teachers often struggle to differentiate between mandatory and mandatory activities. Many mathematics teachers are not prepared to create activities beyond textbook exercises that rely on practical applications. A further exacerbated misalignment is the lack of clear instructions in textbooks or prescribed resources, nor examples of practical tasks (Mandina, 2017). If there is no clear curriculum or coherent teaching, the teacher will be forced to guess the extent and nature of the practical work because it may not always be in line across school or classrooms.

Low Teacher Motivation and Morale

The quality of instruction is influenced by the morale of teachers (Mufanechiya & Mufanechiya, 2011). The absence of high pay, cramped classrooms, insufficient resources and inadequate awards for teachers is prevalent in Zimbabwe (Mandina, 2017). Nevertheless, under these conditions they are less motivated to innovate or allocate more time for planning and carrying out practical work. The task of organizing meaningful hands-on investigations for each group may be too challenging for a mathematics teacher who manages five clasess with 60 students.

The distortion of purpose, triggered by evaluation processes

Practical science and mathematics education should emphasize inquiry-based learning, problem-solving abilities. Zimbabwean educational standards encourage a focus on practical skills through competency-based learning to promote innovation and critical thinking. The purposefulness and effectiveness of practical work are frequently compromised by the persistent distortion of its nature, which is primarily due to the evaluation and assessment processes used in the education system (Maharajh & Musekiwa, 2021). Some research indicates that evaluation processes cause the distortion of practical work's purpose by disproving it. However, other studies indicate similar findings due to these process(s) are significantly lower than those in question. Students in this category are observed to prioritize the completion of practical work tasks, which is primarily due to the use of evaluative questions. Based on the evaluation, practical work approaches may not be realistic due to a congested curriculum and teacher perspectives.

Also, the evaluation of laboratory performance is limited to practical application and is primarily determined by written examinations (Oliveira and Bonito, 2023). This category demonstrates that the utilization of practical work in science classes is affected by the more significant nature of evaluation moments, such as national exams. The evaluation must take into account whether the candidate has conceptual understanding, procedural understanding or not, and if the assessor can demonstrate practical competence. These procedural skills can be generalized, transferrable between environments and easily applicable at any time. Practical skills and competencies, while commonly used in literature on practical work, are rarely defined explicitly from the viewpoint of science teaching. There are practical tests in science, but students can take exams without understanding real work dynamics. The students' capacity to apply the knowledge they acquire in real life will be limited.

Inadequate or erroneous evaluation mechanisms that give precedence to summative results and exam scores result in this distortion (Oliveira and Bonito, 2023). Therefore, practical work is frequently reduced to a superficial, ritualistic activity that fulfills syllabus requirements instead of becoming primarily pedagogical and experiential. In this section, various evaluation processes distort the intended purpose of practical work in science and mathematics education, thereby making it difficult to implement effectively in Zimbabwean schools.

High-Stakes Examinations and Surface Learning

High-stakes national exams are among the most significant sources of distortion. Zimbabwe's ZIMSEC administers public examinations at key educational levels (Grade 7, O-Level, and A- Level). The examinations are frequently grounded in theoretical concepts, and the practical aspects, if they exist, are either simulated or conducted in strict settings that hinder effective investigation and exploration (Maharajh & Musekiwa, 2021). Thus, educators as well as learners tend to focus on passing the test rather than understanding underlying scientific or mathematical concepts (Maharajh & Musekiwa, 2021). When teachers are under pressure to deliver outcomes, they opt for "teaching" to the test and only choose practical tasks that are most likely to be included in exams. Practical activities are converted from exploratory learning experiences into rote exercises (Maharajh & Musekiwa, 2021).. A culture of examination-based focus and emphasis undermines the developmental and investigative purpose of practical work, turning it into a box-checking activity that yields no meaningful learning outcomes.

Fragmentation of Learning Objectives

Theoretical work is intended to be integrated with theoretical material, enhancing learners' comprehension of abstract concepts through practical experience. Assessment practices in Zimbabwe often treat theory and practice as separate disciplines (Maireva & Mabika, 2022). Educators may opt to study theoretical subjects alone, with practical exercises as stand-alone sessions or only during the end of a term, when exams are imminent. This result in a separation between the material students learn in class and their experiences in the laboratory or during mathematical modelling tasks.

The categorization of assessments is a result of their organization. Teachers may receive distinct grades for theoretical knowledge and practical application, often without explicit grading requirements for integration. Thus, the overall purpose of practical work as a means to reinforce and utilize theoretical knowledge is gone. The distortion in this statement is that evaluation systems promote fragmentation rather than integrated learning, which contradicts the objectives of competency-based education.

Tokenistic Implementation for Continuous Assessment

Schools and universities in Zimbabwe have incorporated portfolios and practical tests into their learners' final grades as part of curriculum reforms, which coincide with the move towards continuous assessment. Although this is a positive step, the implementation is often limited because of large class sizes, poor quality materials and tight schedules, educators can produce working results or guide the learner too closely to ensure good results (Bhukuvhani et al., 2010).

The reason for this tokenistic implementation is that it prioritizes documentation and audit trails over the learning process. It is possible for a science teacher to instruct students to replicate the correct results from the board in their laboratory reports, even if they were not conducted or tested. Mathematicians may rush a project through administrative tasks without thorough understanding of mathematical reasoning, for obvious reasons.

The practical work is not a true reflection of scholastic investigative skills, but rather merely manipulated to meet bureaucratic requirements. Evaluation demands that prioritize quantifiable outputs over authentic learning experiences undermine the purpose of practical work as an experiential, student-centred method of education.

Misaligned Rubrics and Overstandardization

The focus on standardization, rather than contextual adaptability, in evaluation rubrics used to assess practical work can also result in distortion. The rubrics used in schools in Zimbabwe are often centrally developed and distributed, with limited flexibility to adapt to different learning environments. School settings in rural areas or with limited financial resources struggle to provide standard laboratory equipment or ICT tools for mathematical simulations, making this particularly challenging (Kadziya, 2020).

Due to the rigidity of rubrics, teachers are compelled to balance student activities against specific criteria that may not accurately reflect their teaching environment. A fundamental mismatch is that teachers and learners tend to view practical work as an externally imposed task rather than an empowering learning opportunity, forcing them into compliance instead of creative adaptation. Also, due to limited resources, students may be penalized unfairly for not following standardized procedures and instead being discouraged from participating in practical tasks (Mangwende & Maharaj, 2019). In this context, evaluation rubrics are designed to promote consistency and fairness, but they undermine the purpose of practical work by suppressing localized innovation and contextual relevance.

Undermining Learner Agency and Autonomy

Competency-based education and learner-centred pedagogy prioritize student agency, which involves encouraging students to take ownership of their learning, ask questions confidently, investigate hypotheses, and make decisions (MOPSE, 2015). This type of agency can be most effective achieved through practical work. Nevertheless, in Zimbabwe, evaluation processes tend to emphasize conformity to procedures rather than independent thinking.

Students must adhere to specific procedures, implement particular techniques, and reach predetermined outcomes. Any deviation, whether scientifically or mathematically significant, is punished rather than encouraged. The unrelenting hierarchy hinders the development of practical skills such as creativity, critical thinking, and problem-solving. In this instance, the disarray is a consequence of assessment frameworks that prioritize replication over reasoning, leading to an unencumbered learning culture that suppresses curiosity and engagement.

Economic, organisational and environmental challenges

Practical work in science and mathematics education is widely recognized as essential for the development of experiential learning, critical thinking skills, and problem-solving. Yet in Zimbabwe, this ideal faces significant limitations due to socio-economic contexts, institutional constraints and environmental disparities. A lack of resources in under-resourced schools has resulted in a mismatch between curriculum expectations and classroom realities due to these obstacles. Babalola et al. (2020) and Ruparanganda et al. (2013) indicate restrictions based on economic, organizational or environmental factors. In countries with limited economic resources, research learning is less common because practical work demands the use of new and modern equipment, which also provides an adequate space for effective participation in practical investigations. Schools' inability to afford laboratory equipment and technical assistants can hinder teachers from carrying out their practical duties, as highlighted by funding restrictions (Ruparanganda et al., 2013). The current state of affairs may lead to a continuous disengagement from scientific and mathematical courses and their professional lives (Tesfamariam et al., 2014; Adamu et al, 2020). Due to limitations, practical work like field outings is not commonly done in schools. This may be due to the belief that knowledge is gained through classroom learning, which is typically facilitated by teachers and students. Out-of-school experiences are frequently disregarded and field trips have several limitations, such as the need for time planning, limited transportation and accommodation budgets, large classes, compliance issues with subject programs, and lack of preliminary preparation.

Economic Constraints

The long-standing economic challenges faced by Zimbabwe have had a significant impact on the education sector, particularly in terms of high-quality science and mathematics practicals (Mandina, 2017). The primary issues stem from a shortage of funds allocated to education, which results in inadequate resources for labs, consumables and teaching materials required for effective practical learning.

Inadequate Budgetary Allocation

The education sector has received a consistent share of the national budget, but its funding for practical-based learning has often been inadequate. In many cases, funding is concentrated on examination fees, teacher salaries, and administrative expenses, with little or no allocation of funds for laboratory equipment or mathematics manipulatives (Mandina, 2017).

The high cost of laboratory equipment and consumables

Specialized equipment and chemicals are essential for science practical work in fields like chemistry, physics, and biology, which can be expensive and difficult to replenish. Practical mathematics work, such as geometry and data handling may necessitate the use of tools like protractors, mathematical sets, and graphing materials (Mandina, 2017). The majority of schools, particularly those in rural areas, operate on tight budgets or rely solely on School Development Committees (SDCs) making it almost impossible to obtain these resources regularly. Moreover, the rising cost of imported equipment is being compounded by inflation and changing currency rates.

Household Poverty and Learner Contribution

Due to financial difficulties, parents and guardians in many schools in Zimbabwe are now responsible for financing educational materials (Mandina, 2017). The absence of access to basic materials like exercise books, calculators, or science kits can hinder learners from participating in practical tasks. Additionally, some families may not be able to afford such items (Magwende & Maharaj, 2019). The inability of households to afford education also affects student attendance and concentration, leading to a decrease in the effectiveness of practical lessons.

Organizational Constraints

The Ministry of Primary and Secondary Education (MoPSE), schools, and teacher training institutions are confronted with organizational and systemic challenges that hinder the full implementation of practical work in science and mathematics education, besides economic constraints.

Insufficient Teacher Training and Professional Development

Although practical lessons are included in the syllabus of teacher education institutions in Zimbabwe, the training itself lacks the depth to provide teachers with the confidence and creativity to teach using minimal resources (kadziya &Ndebele, 2020; Mutseekwa, 2021). Practical pedagogies are not commonly included in training, which is why many mathematics and science teachers prefer to teach only theoretical subjects (Mufanechiya & Makgalwa, 2024). In addition, there are limited opportunities for ongoing professional development in rural areas, particularly where travel and internet connections are expensive and convenient (Mufanechiya & Makgalwa, 2024). As a consequence, numerous educators are incapable of devising innovative or improvising practical tasks using resources that are readily accessible.

Curriculum Overload and Examination Pressures

Practical skills are highly emphasized in the Zimbabwean curriculum. In reality, teachers tend to concentrate on theoretical coverage due to the workload of high-stakes exams and curriculum overload (Magwende & Maharaj, 2019). It is common for science and mathematics teachers to rush through syllabi and prepare students for final exams, with little time left for meaningful work. Thus, practical work is either disregarded or treated as a last-minute activity to prepare for practical aspects of standardized tests.

Administrative Support and Resource Management

An additional impediment is the absence of administrative delegation to handle practical tasks. A lot of schools prioritize exam success over the learning experience (Mandina, 2017). The limited attention can result in the inadequate funding of practical components or the lack of utilization of laboratory areas (Magwende & Maharaj, 20219). The absence of qualified laboratory technicians and storekeepers leads to inadequate resource management, resulting in broken equipment, stockouts of chemicals, or the loss of small mathematical kits (Mandina, 2017).

Environmental Constraints

The practical work in Zimbabwe is largely dependent on factors such as its geographic location, climate and infrastructure. The disparity in educational quality is exacerbated by specific challenges faced by schools located in rural, remote, or climate-vulnerable regions.

Rural-Urban Disparities

There's a significant difference between the amount and quality of practical facilities available in cities and towns (Mandina, 2017). Many of these urban schools, formerly reserved for white students during the colonial period, have modern labs and better funding. Nevertheless, the majority of rural schools face challenges such as ill-fated roads and inadequate water supply for conducting science experiments or engineering-based mathematics practicals (Mandina, 2017). The sharing of outdated or damaged laboratory equipment among large groups can hinder individual learning and engagement (kadziya &Ndebele, 2020). The absence of ICT infrastructure in rural schools also limits the potential for virtual simulations or blended learning methods to supplement physical practical work.

Climate and Environmental Hazards

Droughts, cyclones and flooding disrupt many schools in Zimbabwe due to climate change (Musarandega & Masocha, 2023). In areas such as Chimanimani and Binga, weather-related hazards frequently lead to the collapse of school structures, loss of study time, and displacement of both students and teachers (Musarandega & Masocha, 2023). Additionally, the outcome is a learning environment that reduces practical work in light of survival needs. Also, there are environmental constraints that affect the availability of local resources. There is a lack of institutional guidance and support for integrating the enviroment, into standard teaching practices in science and mathematics.

Health and Safety Concerns

Health and safety concerns are frequently raised when performing practical tasks, such as operating with chemicals, electricity or using sharp tools. Schools that lack proper safety gear, such as gloves, goggles and fire extinguishers, are often under-funded. Practical work is often discouraged by teachers who are concerned about potential accidents and legal consequences, particularly when teaching large numbers in unsuitable areas.

Figure 5.1 shows the conceptual frame work on barriers to implementation of practical work in science and mathematics education.

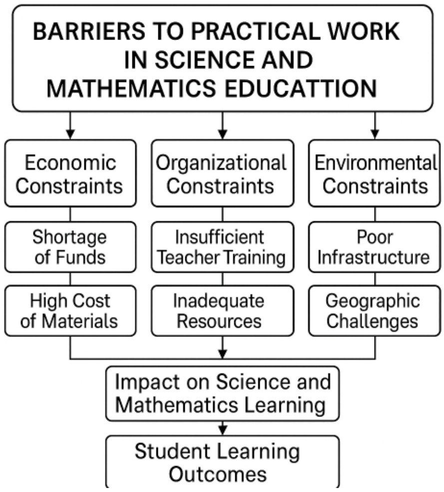

Fig 5.1 Conceptual framework

The conceptual framework on Barriers to Practical Work in Science and Mathematics Education presents a visual representation of the various hindrances that hinder the effective implementation of practical work in schools throughout Zimbabwe. The model categorizes the hindrances into economic, organizational, and environmental domains, which are further broken down into sub-barriers such as inadequate funding, teacher capacity gaps, or infrastructure deficiencies. These interconnected barriers are not isolated issues but rather cumulative and detrimental to the teaching and learning of science and mathematics.

The framework underscores the direct effects of these barriers on student learning outcomes. The factors include reduced participation in experimental or problem-solving activities, limited enhancement of critical thinking and practical skills, and subpar performance in science and mathematics assessments. Thus, students commonly graduate from school with inadequate skills to pursue tertiary education or STEM-based careers.

Proposed solutions to implementation barriers and model

In order to address the financial limitations that prevent the effective delivery of practical work in schools, the Ministry of Primary and Secondary Education (MoPSE) should allocate funds exclusively to practical science and mathematics education. This can be achieved through the use of existing support mechanisms like the Basic Education Assistance Module (BEAM), which can also include provision of resources for practical work. In addition, collaborations with NGOs and private sector entities such as those in the mining, agricultural or telecommunications sectors can provide critical support like laboratory equipment, learning materials and scholarships to poor children.

An alternative approach to saving money is to promote the use of locally produced, inexpensive resources for practical purposes. Educators can be trained to use both locally sourced and recycled materials in their teachings, including plastic bottles for measuring, maize stalks for biological modeling, and clay for creating geometrical shapes. Locally produced and tailored improvisation manuals for schools in Zimbabwe should be included to aid students in improving skills. Also schools have the opportunity to explore income-generating ventures such as school tuckshops, school garden projects and poultry farming. The profits obtained from these initiatives can be utilized to replenish the availability of useful resources, creating a sustainable funding source that encourages school-age self-reliance.

It is necessary to enhance teacher competence and support structures through organizational means. It is necessary to have mandatory PCPD programs that emphasize practical work, curriculum-based learning, and the innovative use of low-cost resources. Schools in rural areas with limited resources can benefit from the cluster-based training model, which enables them to share training opportunities and resources within the same area.

The curriculum alignment should not imply that practical work is an additional or optional activity. This is a fundamental requirement in the daily teaching and learning process. The process involves modifying lesson plans, assessment rubrics, and time allocations to ensure that teaching incorporates practical investigations and mathematical modeling. To reduce the burden on learners and teachers, it is important to streamline the curriculum by eliminating redundant or overlapping content and allowing for inquiry-based learning through project-oriented learning.

It is also important to strengthen school leadership. Responsibilities for school leaders include resource mobilization, laboratory supervision, and pedagogical supervision. Training in these areas will enhance their ability to support the implementation of practical work. Also, it is recommended that schools assign designated personnel to coordinate laboratory or practical work activities, even if there are no fully equipped laboratories. Ensure that practical activities are consistently planned and organized within the school system.

In terms of environmental concerns, there is a pressing need to invest in infrastructure for science and mathematics education, especially in rural and marginalized regions. The establishment and maintenance of basic science laboratories should be the joint effort of government and community partners. Mobile laboratories that spread throughout schools within a cluster can provide an interim solution in areas where access to equipment and materials is limited or unattainable. This type of technology provides this opportunity.

Information and Communication Technology (ICT) advancements provide extra avenues for practical learning. The introduction of low-bandwidth simulation software is possible for schools with limited connectivity. They can distribute these simulations via donors' programs, or government-provided tablets or laptops. In addition, national media platforms such as radio and television can broadcast practical demonstrations that can be followed or replayed by learners and teachers in real time.

Ultimately, the learning becomes more meaningful and interesting as practical work is integrated with local challenges. It is possible for projects to cover areas such as waste management, water purification, small-scale farming, or weather monitoring, which are directly relevant to learners' daily lives. By encouraging students to conduct experiments at home and present their results in class, we foster a spirit of inquiry, independence, and innovation that transcends some of the infrastructure challenges faced by school environments.

Proposed Practical work model

The Science and mathematics Practical Work Implementation Model (see figure 5.2), offers specialized, contextually grounded methods for improving the quality and accessibility of hands-on learning. Students engage in inquiry-based, locally relevant activities in science and mathematics through the "Practical Work Core" that is anchored at the centre. Its core is surrounded by essential support systems including continuous professional development (CPD) for teachers, community-based resource mobilization, and infrastructural innovations such as mobile labs and ICT tools. The model is based on operational strategies that emphasize formative feedback, instruction by learners, and the implementation of real-world projects that address local issues in Zimbabwean communities. Based on national curriculum guidelines and responsive to economic, organizational, and environmental barriers in varying educational settings, this model provides a flexible framework for inclusive, sustainable, effective, practical education across the country.

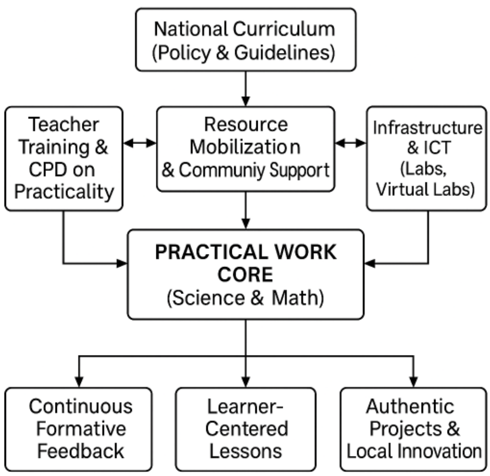

Fig 5.2 Science and mathematics Practical work Implementation model

In the proposed model, the main pillar is Practical Work Core, which provides "the first real environment for hands-on and reflective learning experiences across all science and mathematics subjects. In mathematics, students work on real-world problems such as geometry modeling with clay or string, local statistical data analysis, and using spatial reasoning by mapping local areas. Within the science curriculum, students conduct chemical experiments with locally available reagents, perform ecological surveys within their communities, and take on engineering design challenges with accessible materials such as wire, wood, or recycled plastics. The practical applications of theoretical knowledge are ensured through these engagements.

Several interrelated systems support the core work, which is crucial for maintaining and improving the sustainability of practical work. Teacher Training and Continuous Professional Development (CPD) play a crucial role in teaching, as they require content and knowledge of local materials to be effective. Schools should function as centers of exchange for teachers' perspectives, collaboration on innovations and regular upskilling. In addition, Resource Mobilization and Community Engagement have a crucial function. It strengthens its practical work by working closely with local councils, private sector entities and NGOs to provide funding for projects as well as equipment and logistical support. Locally available materials are being offered, and parents and other community members are also participating.

Common and mobile laboratories are implemented to address infrastructure needs, particularly in rural or under-resourced schools. Integration of infrastructure and ICT should be integrated to ensure access in off-grid areas. Basic science/math kits should also be distributed, along with digital resources such as simulations loaded onto USB drives or solar-powered tablets for schools. The absence of traditional lab facilities enables learners to engage in practical exercises.

Through the use of Operational Strategies, implementation is maintained to meet pedagogical objectives and remain effective. Teacher feedback is continuous and involves a range of methods, including direct observation during tasks, learner portfolios (such as questions questioning prompt), reflective journals, and peer or self-assessments to gauge understanding and guide instruction. Learner-Centered inquiry-based learning is promoted through practical activities that incorporate the local environment and encourage student collaboration on problem-solving tasks. This technique promotes critical thinking and an increased attentiveness to the material being taught.

Finally, a real projects is part of the model. Community-based interdisciplinary projects are completed by learners every school term. Such initiatives can encompass projects such as designing and building basic weather stations based on household items, applying business mathematics concepts to local market prices, or understanding environmental science through real-time testing of water sources. The model ensures that practical work is not only accessible but also meaningful and relevant to both learners and communities by incorporating real-world problems into its learning.

Conclusion

The implementation of practical work in science and mathematics education in Zimbabwe is both an urgent need and a potential opportunity for transformative learning. The challenges faced in practical instruction are not limited to economic, organizational and environmental constraints alone, so this chapter has outlined realistic and sustainable solutions that address these barriers at many levels. This model presents a holistic approach that highlights practical work as the primary focus of instructional planning, supported by policy, teacher training, community engagement, and innovative infrastructural approaches. Integrated formative assessment, contextual relevance, and authentic learner tasks are integrated into the model to ensure that practical work is an integral part of everyday learning, rather than a secondary task. Practical work in Zimbabwe depend largely on commitment of policymakers, educators and communities as well as learners themselves to work together to foster the development of competencies, creativity and linking learning to real-life problems in society.

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