AQUADEMIA
2024, 8(1), ep24004
ISSN 2542-4874 (Online)
https://www.aquademia-journal.com/

Research Article

OPEN ACCESS

Transforming science teaching in Namibia: A practical work inquiry framework for secondary schools

Tomas Shivolo [1*]

[1] The International University of Management, Windhoek, NAMIBIA
***Corresponding Author:** t.shivolo@ium.edu.na

Citation: Shivolo, T. (2024). Transforming science teaching in Namibia: A practical work inquiry framework for secondary schools. *Aquademia, 8*(1), ep24004. https://doi.org/10.29333/aquademia/14698

ARTICLE INFO

Received: 16 Feb. 2024

Accepted: 25 May 2024

ABSTRACT

This study presents the practical work inquiry practice framework, which is designed to improve science practical work and inquiry-based instruction in secondary schools in Namibia. The framework has been developed based on both theoretical and empirical research. The study conducts a thorough examination of existing literature to identify research gaps in existing studies. It emphasizes the significant impact of teachers' beliefs and external influences on the process of lesson planning. The framework aims to bridge the gap between teachers' views and the actual implementation of the science curriculum, functioning at the macro, meso, and micro levels of education. It includes various aspects such as strategic planning, training for teachers, designing the curriculum, providing resources, implementing lessons in the classroom, giving feedback, fostering collaboration, monitoring progress, evaluating outcomes, providing ongoing support, involving stakeholders, promoting a positive school culture, demonstrating leadership, supporting teachers, addressing learner diversity, and engaging the community. The aspects are classified into strategic, tactical, and operational functions that are interconnected to enhance scientific teaching methods. The established framework offers a complete and contextually applicable method to implementing science practical work in Namibian secondary schools. This approach is based on inquiry-based instruction and aims to increase overall education.

Keywords: practical work, inquiry practice, teachers' beliefs, inquiry-based instruction, Namibian teachers

INTRODUCTION

Within the realm of science education, the refinement of teaching methodologies holds paramount importance in nurturing future generations equipped with scientific expertise (Bugingo et al., 2022; Idris et al., 2023; Imaduddin & Zuhaida, 2019; Kiang & Colanero, 2020; Lisao et al., 2023). This study endeavors to establish and delve into a framework tailored to enhance scientific instructional practices within the context of Namibia. Specifically, the study centers on the practical work inquiry practice framework (PWIPF), derived from the research findings and insights garnered from the author's doctoral work. Through an exploration of Namibian science teachers' conceptions regarding the enactment of science practical work via inquiry-based instruction, the research aims to unpack, examine, and comprehend the multifaceted aspects of PWIPF and its potential to enrich the integration of hands-on activities and inquiry-driven teaching techniques in the science education landscape of Namibia.

Namibia, akin to many other countries, acknowledges the essential role of practical work and inquiry-based approaches in science education (Liswaniso, 2019; Shikongo, 2022; Shinana, 2019; Shivolo, 2018; Shivolo & Ramnarain, 2020). These pedagogical strategies not only facilitate a hands-on scientific principle but also foster critical thinking, problem-solving abilities, and an authentic learning among learners about the natural world. Nonetheless, the effective implementation of these practices necessitates a carefully devised and contextually relevant framework that addresses the distinctive challenges and opportunities within Namibian science classrooms.

As the researcher embarks on this exploration, it becomes imperative to consider the educational landscape of Namibia. Factors such as resource constraints, diverse learners' backgrounds, teachers' intrinsic and extrinsic behavior in enacting science practical work, and varying infrastructure present distinctive challenges that demand a subtle strategy to curriculum development (Akuma & Callaghan, 2019a, 2019b; Jayawardena et al., 2020; Shivolo, 2018; Shivolo & Ramnarain, 2020; Thibaut et al., 2019). Researchers often engage in debates about teachers' quality in influencing learners' academic achievement (Sancar et al., 2021), which are aimed at improving their classroom teaching practices (Finkelstein et al., 2021; Santos et al., 2019). The focus of the author's doctoral study aimed to explore the following objectives:

(a) determine the science teachers' views of inquiry-based instruction,

(b) establish how science teachers' views of inquiry-based instruction facilitate science practical work,

(c) identify factors affecting teachers' usage and enactment of inquiry-based instruction in their science practical work, and

(d) propose a framework for improving science practical work in Namibian secondary schools.

This research study revealed that a significant majority of Namibian science teachers possess substantial knowledge and understanding of inquiry-based instruction and the essence of teaching science through the enactment of science practical work. However, there is a notable gap in the enactment of these approaches within their classrooms. Over 80% of the participants in this study identified key challenges impeding the successful implementation of inquiry-based instruction through practical work, including insufficient resources, limited time for conducting science investigations, teachers' behavior, work overload, disruptive conduct of learners, and the nature of technical support provided to teachers by their senior officials such as the senior education officers responsible for science subjects.

The development of PWIPF thus ensued as a direct outcome of these specified the findings of the researcher's doctoral study. Furthermore, it is vital to underscore that the development of PWIPF was informed by a review of relevant literature, theoretical and conceptual frameworks integral to this study, and consequently, the implications derived from the research findings. The systematic review as a methodological approach has ensured that PWIPF is grounded in a comprehensive and academically rigorous foundation. Utilizing a framework in the context of science education is pivotal for enhancing teaching practices by providing a structured and systematic approach (González-Pérez & Ramírez-Montoya, 2022; Moullin et al., 2020). A well-designed framework serves as a guiding structure that aligns various elements critical to effective teaching, such as lesson planning, curriculum design, professional development, resource allocation, and classroom implementation (You et al., 2021; Yurtseven Avci et al., 2020). It offers an organized pathway for teachers to navigate the complexities of science instructional approaches, addressing challenges and gaps identified through systematic reviews and analyses. By employing a framework, teachers gain a comprehensive view of the interconnected components involved in science education, enabling them to bridge the gap between theoretical knowledge and practical implementation (Akuma & Callaghan, 2019b; Ortiz-Revilla et al., 2022). This structured approach not only supports teachers in aligning their instructional strategies with educational objectives but also fosters a more consistent and integrated learning experience for learners, ultimately contributing to improved science educational outcomes.

PWIPF thus emerged as a potential solution, offering a structured and adaptable guide that can be tailored to the specific needs of Namibian science teachers. The significance of this research extends beyond theoretical discourse; it directly addresses the practical aspects of science education in Namibia. By unpacking PWIPF, the researcher aim to provide insights into its implementation, elucidate its impact on science classroom dynamics, and contribute valuable perspectives to the ongoing discourse on science education reform. This study not only underscores the importance of adapting global educational frameworks to local contexts but also emphasizes the mutual relationship between theory and practice in the pursuit of educational excellence (Wang et al., 2019).

In the subsequent sections, the researcher will probe into the components of PWIPF, explore its theoretical underpinnings, analyze its potential benefits for Namibian science education, and offer recommendations for its effective integration into classroom practices. Through this complete examination, the researcher aspires to provide a roadmap for teachers, policymakers, and researchers keen on improving the quality of science education in their classrooms and in Namibia particularly and, by extension, contributing to the global discourse on innovative pedagogical approaches. This paper therefore aims to provide insights into enhancing the teaching of science practical work through inquiry-based instruction in Namibian schools through the enactment of PWIPF.

LITERATURE REVIEW

Science Practical Work

In many countries, science education has primarily focused on practical work (Lee & Sulaiman, 2018; Sshana & Abulibdeh, 2020; Wei et al., 2019). Practical work as a central construct of teaching science in the 21st century encompasses activities requiring learners to observe and manipulate real-world objects and materials, either independently or collaboratively (Lee & Sulaiman, 2018; Sshana & Abulibdeh, 2020). According to the National Research Council (2012), practical work may also encompass activities that expose learners to data about the natural world, not necessarily related to their immediate environment. Often referred to as 'laboratory work,' practical work involves various hands-on activities used by teachers in teaching science at both primary and secondary school levels (Akuma & Callaghan, 2019a; Akuma & Gaigher, 2021; Gericke et al., 2023; Kaindume, 2018; Ndoro, 2017; Ntawuhiganayo & Nsanganwimana).Various definitions of practical work have been identified in various studies, even though there had not been a proper definition of science practical work in literature for about a century. Some believe that practical work comprises learners engaging in hands-on experimentation in a laboratory or classroom, while others believe that practical work entails learners engaging in laboratory work or experiments as part of a teaching demonstration (Akuma & Callaghan, 2019a; Akuma & Gaigher, 2021; Tsakeni, 2022; Wei et al., 2019).

The terms 'laboratory work' and 'practical work' are thus often used interchangeably in most cases. Practical work can refer to experiments carried out anywhere, including outside the classroom, inside the classroom, and in the laboratory, whereas laboratory work pertains to experiments conducted particularly in a laboratory (Wei et al., 2019). Learners may use the term 'laboratory' to describe a place, where they can test their unique ideas and/or interpretations of the things and events they discover as they investigate the universe in which they find themselves. Furthermore, the term 'practical work' can be used to describe a setting, where science learners engage in hands-on activities such as observations and experiments, not only to verify, but also to find, or discover new information (Akuma & Callaghan, 2019b; Constantinou & Fotou, 2020; Sshana & Abulibdeh, 2020; Spaan et al., 2022; Wei et al., 2021). The laboratory is unique in that it allows learners to explore and ask questions in addition to displaying objects, ideas, processes, and experiments.

Accordingly, practical work has been consequently defined as a variety of experiences that take place in a science school setting, where learners engage with objects, tools, or other sources of information that are primarily out of their reach, but that they could use to observe and conceptualize their natural surroundings (Akpan et al., 2021; Akuma & Callaghan, 2019a, 2019b; Akuma & Gaigher, 2021; Spaan et al., 2022; Wei et al., 2019). Practical work in science classes can thus include both hands- and mind-on activities such as laboratory experiments.

Learners do experiments on their own with hands-on and mind-on activities, with the teacher serving as a facilitator. Practical work, in general, can involve any form of inquiry or experimentation by learners through their own or even in groups, as well as teacher demonstration (Akuma & Callaghan, 2019a, 2019b; Sshana & Abulibdeh, 2020). Shivolo (2018) outlined that practical work may also refer to any form of learner-based activities that are employed by teachers as teaching and learning strategies. Even though the reviewed research revealed that articulating the construct 'practical work' in literature has been challenging and confusing, many science scholars claimed to have reached a consensus. As a result, they have agreed on a common understanding of what the notion comprises and have divided practical work into three categories: core activities, directly related activities, and complimentary activities (Sshana & Abulibdeh, 2020; Wei et al., 2019, 2021). Since there are so many kinds of practical work, some may comprise teacher-led demonstrations and/or experiments led by learners in groups or alone (Shivolo, 2018). As a result, and for the purposes of this study, practical work, as defined by the researchers in the preceding paragraphs, entails learners actively participating in activities that pique their interest in learning new information about the scientific phenomena under study.

Three Common Forms of Science Classrooms

Practical work in science classrooms is a crucial component of science education, providing learners with hands-on experiences that deepen their understanding of theoretical concepts and foster essential scientific skills. There are three primary forms of practical work commonly employed in science classrooms: experiments, investigations, and demonstrations (Manz et al., 2020).

Experiments

Experiments involve a systematic and controlled approach to testing hypotheses and theories (Cakiroglu et al., 2020). During experiments, it is expected thar learners should actively manipulate variables, collect data, and analyze results to draw conclusions. The hands-on nature of experiments allows learners to engage with the scientific method, fostering critical thinking and problem-solving skills (Idris et al., 2022; Ngozi, 2021; Saad, 2020; Saputro et al., 2019). Additionally, experiments help learners develop a deeper appreciation for the importance of accuracy and precision in scientific inquiry and phenomena (Ngozi, 2021; Recker, 2021; Saputro et al., 2019). For instance, in a biology class, learners might conduct an experiment to investigate the effects of different environmental factors on plant growth. Similarly, a physics class, learners may assemble equipment and apparatus to investigate how different factors influence the resistance of a conductor. In all examples, the process of experimentations, not only help learners to learn about the specific topic but also develop essential skills such as measuring, recording data, and drawing meaningful conclusions.

Investigations

Investigations, on the other hand, are broader and often involve more open-ended exploration of scientific phenomena (Elesio, 2023; Oliveira et al., 2021). Unlike experiments, investigations may not have a predetermined outcome, encouraging students to explore and discover patterns or relationships independently (Manz et al., 2020). This form of practical work promotes creativity and curiosity, allowing students to develop a sense of ownership over their learning (Morado et al., 2021). In a chemistry class, for instance, learners might be tasked with investigating the factors that affect the rate of a chemical reaction. This type of practical work encourages learners to design their own procedures, formulate hypotheses, and analyze results, fostering a deeper understanding of the scientific process and the scientific phenomena being investigated.

Demonstrations

Demonstrations play a vital role in science education by providing learners with opportunities to observe and learn from the expertise of their teachers (Shivolo, 2018; Shivolo & Ramnarain, 2020). While not as hands-on as experiments or investigations, demonstrations offer a valuable means of illustrating complex concepts, showcasing scientific principles, and sparking curiosity (Lucz & Milner-Bolotin, 2022; Tembrevilla & Milner-Bolotin, 2019). Demonstrations often involve the use of specialized equipment or techniques that may be challenging for learners to replicate individually (Shivolo, 2018). For instance, in a physics class, a teacher might conduct a demonstration of gravitational forces using a pendulum, while learners are observing. This not only helps learners visualize abstract concepts but also emphasizes the importance of safety and proper experimental technique. Demonstrations, when followed by class discussions, encourage learners to ask questions and deepen their understanding through dialogue.

To this end, the common three forms of practical work in science classrooms namely: experiments, investigations, and demonstrations, collectively contribute to a holistic and effective science education. These activities go beyond textbook learning, providing learners with the opportunity to apply theoretical knowledge, develop critical skills, and cultivate a genuine appreciation for the scientific process. Through a combination of hands-on experimentation, open-ended investigations, teacher-orchestrated and learner-orchestrated demonstrations, learners can develop a well-rounded understanding of scientific principles, preparing them for future academic pursuits and real-world applications.

Inquiry-Based Learning

Owing to the ambiguity found in the existing literature regarding the characterization of inquiry in diverse research endeavors (Fitzgerald et al., 2019; Nollmeyer & Baldwin, 2022; Rosen, 2019; Zhang & Cobern, 2021), this study specifically probes into the context of inquiry within a science classroom, emphasizing its manifestation in instructional methods and its purpose during science practical activities. The terminology ‘inquiry-based instruction’ is employed in this research to conceptualize the teaching approach to teaching science practical work in Namibian schools, where learners are expected to be active participants of knowledge creation rather than being passive receivers of information from the teacher. It is essential to highlight that the terms ‘inquiry-based instruction’, inquiry-based learning and ‘inquiry-based science instruction’ are used interchangeably in this study, referring collectively to inquiry-based learning approaches, inquiry-based teaching methods, or simply the concept of inquiry. While these terms may carry distinct meanings in broader contexts, for the purpose of this study, they are considered synonymous, and each will be used in lieu of the other as needed.

Engaging learners in practical activities is recognized as a method aimed at enhancing learners’ understanding of science concepts and enhance their ability to address scientific challenges (Bao & Koenig, 2019; de Jong, 2019; Lee et al., 2020). This approach facilitates a deeper understanding of the scientific process by allowing learners to replicate the actions of scientists. Numerous scholars in the field of science education have characterized inquiry-based instruction as a contemporary and widely adopted teaching approach, extensively implemented in global science classrooms (Chikaluma et al., 2022; Duncan et al., 2021; Ministry of Education [MoE], 2005; Mlipha, 2022; Mohammed et al., 2020; Nicol et al., 2020; Ssempala, 2020; Van Graan, 2020). This instructional method aims to enable learners to acquire knowledge and skills in a lasting and meaningful manner, as evidenced by the works of Twahirwa and Twizeyimana (2020).

Twahirwa and Twizeyimana (2020) argue that fostering suitable and accommodating educational environments amplifies strategies essential for facilitating the inquiry-learning approach. Some scholars have contended that specific contextual constraints hinder the incorporation of scientific practical work due to various factors such as the absence of traditional laboratories, equipment, qualified and motivated teachers (Aydin & Boz, 2013; Gess-Newsome, 2013; Lee & Sulaiman, 2018; Makori & Onderi, 2014; Shivolo, 2018; Twahirwa & Twizeyimana, 2020). Consequently, educators are recognized as pivotal workforce and educational stakeholders crucial for the successful execution of inquiry-based instructions in science classrooms (Twahirwa & Twizeyimana, 2020).

This educational approach enhances learners’ understanding of scientific phenomena by encouraging collaborative discussions with peers, shifting the emphasis from rote memorization to active engagement. Furthermore, it empowers learners to take charge of their learning, fostering increased engagement with the material. Inquiry-based science instruction adopts an investigative teaching and learning approach, offering learners opportunities to explore problems, seek solutions, make observations, pose questions, experiment with ideas, and think creatively and intuitively (Marshall et al., 2017; Mokiwa & Nkopodi, 2014; Ramnarain & Hlatswayo, 2018; Sotáková et al., 2020).

In this sense, inquiry-based instruction in science involves learners doing science in situations, where they can explore potential solutions, develop explanations for the phenomena under investigation, elaborate on concepts and processes, and evaluate or assess their understandings considering available evidence. This teaching method is based on teachers recognizing the importance of presenting learners with problems that will challenge their current conceptual understandings, forcing them to reconcile anomalous thinking and construct new understandings.

Use of Frameworks for Educational Improvement

Frameworks play a pivotal role in the sphere of teaching and learning, especially in the field of science education, as they provide teachers with structured and systematic approaches to enhance the quality of instruction (Fauth et al., 2019; Ortiz-Revilla et al., 2020). The essence of using frameworks in teaching lies in their ability to serve as comprehensive guides, offering teachers a well-organized structure that aids in the planning, implementation, and assessment of instructional strategies (Jassim, 2022; Winkelmes et al., 2023). By utilizing frameworks, teachers can create a cohesive and consistent learning experience, ensuring that important concepts are covered effectively and that learners receive a well-rounded education.

In the context of science teaching and learning with a focus on the implementation of science practical work the enactment of inquiry-based instruction, frameworks are instrumental in improving the overall quality of education. According to Caena and Redecker (2019), frameworks help teachers align their teaching methodologies with established learning objectives, ensuring that the curriculum is thorough and addresses key scientific principles. Additionally, frameworks assist in fostering critical thinking skills among students, encouraging them to approach scientific problems methodically and analytically (Byrd & Asunda, 2020; Okolie et al., 2022). This approach not only enhances their understanding of scientific concepts but also equips them with valuable skills for lifelong learning.

Conceptual & Theoretical Frameworks

Conceptual framework

This study has been developed based on the research gap identified in terms of teaching science practical work through inquiry-based instruction in Namibia. As a result, a conceptual framework has been developed in a bid to understand the research problem. The context of unpacking the research problem and giving possible interpretations, the theoretical lenses has been developed in helping to understand, interpret and analyze the research problem. This conceptual framework has been developed in accordance with the research objectives

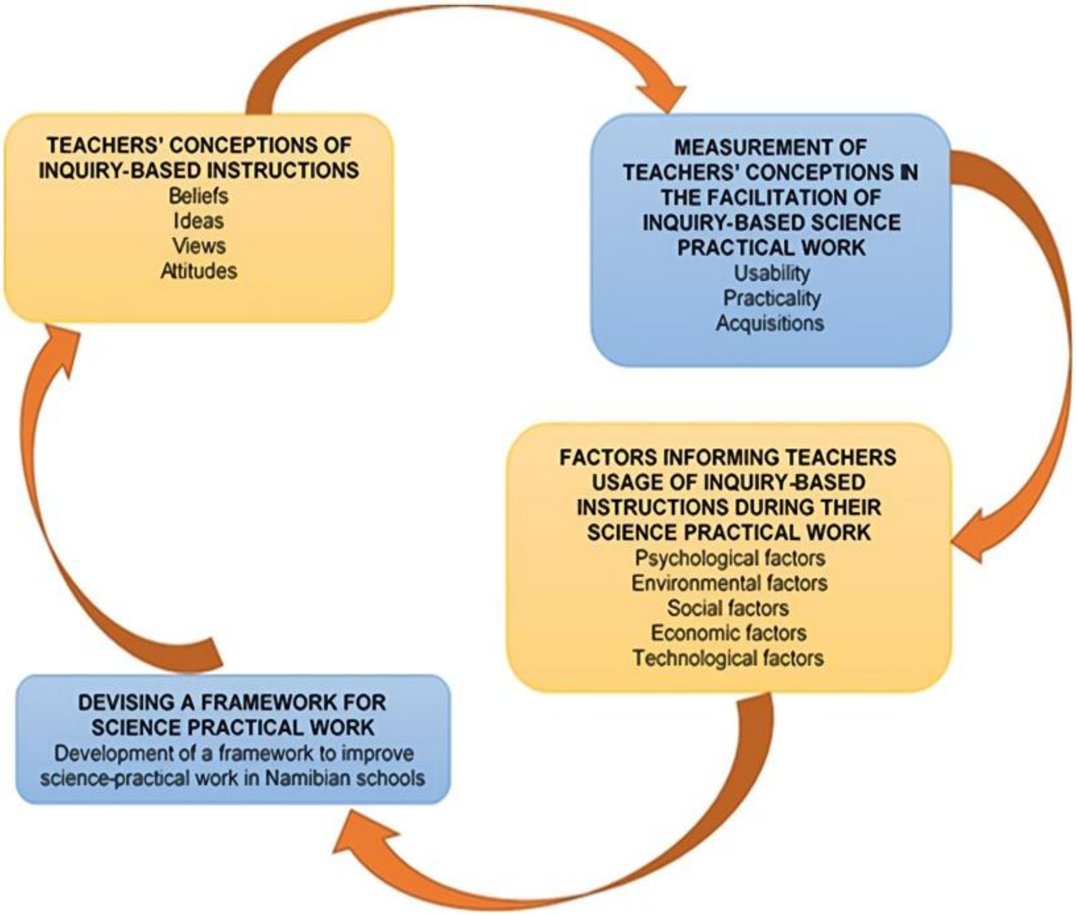

Figure 1. Conceptual framework (Source: Author)

of the first author's doctoral study. **Figure 1** depicts the conceptual framework underpinning this study as developed by the researcher.

This research is founded on the identified gap in the literature pertaining to the implementation of science practical work using inquiry-based approaches to teaching in Namibia. Consequently, a conceptual framework has been formulated with the aim of grasping the research issue. The development of conceptual perspectives aids in unpacking the research problem, offering potential interpretations, and facilitating an analytical understanding of inquiry-based instructional approaches in Namibian science classrooms. The formation of this conceptual framework aligns with the research objectives outlined in the doctoral study conducted by the first author. The researchers have illustrated the conceptual framework guiding this study in **Figure 1**.

The research plan refinement involved a systematic four-step process, as illustrated in **Figure 1**. The initial step dwelled into examining teachers' conceptions of inquiry-based instructions. Subsequently, the second step focused on quantifying these conceptions concerning the facilitation of science practical work. The third step honed on identifying the factors influencing teachers' utilization of inquiry-based instruction during science practical work. The final step concentrated on formulating a comprehensive framework for science practical work, which is the focus of this study.

The development of a conceptual framework for research necessitates an inductive approach, wherein individual elements are gathered and interconnected to construct a broader map of potential relationships (Imenda, 2014; Majeed et al., 2023). This conceptual framework functions as a system of interconnected concepts, assumptions, and beliefs that researchers employ to underpin and direct their research plans (Grant & Osanloo, 2014).

Figure 1 portrays the conceptual framework utilized in this study, aiding the researcher in shaping the research plan to comprehend how teachers' conceptions of inquiry-based instruction, encompassing beliefs, ideas, views, and attitudes, contribute to the evaluation of their effectiveness in facilitating science practical work in terms of usability, practicality, and skill acquisition. Moreover, teachers' facilitation of science practical work using inquiry-based instruction is informed by several factors, such as psychological, environmental, social, economic, and technological (Akuma & Gaigher, 2021; Bilican et al., 2021; Cairns & Areepattamannil, 2019; Tal et al., 2019). All these factors collectively are deemed to help conjecture and devise a framework that could be used to improve the enactment of science practical work in the Namibian science classroom. A conceptual framework is thus, derived from concepts, whereas the theoretical framework originates from a set of theories, as shown in **Figure 2**, and developed by Imenda (2014).

As it can be seen in **Figure 2**, a researcher should not confine a particular study to a sole theory when addressing a research problem. Instead, the study should be connected to a collection of concepts that effectively contribute to the understanding of the research inquiry (Grant & Osanloo, 2014; Imenda, 2014).

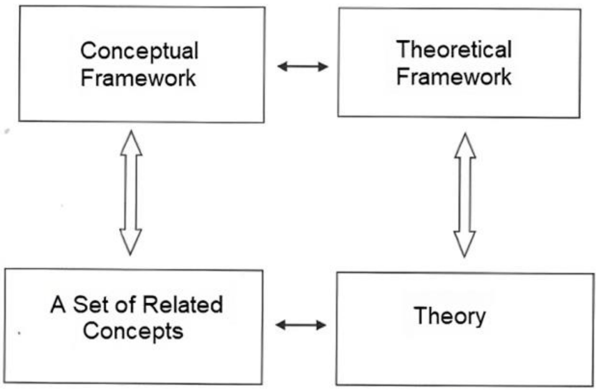

Figure 2. Derivation of conceptual & theoretical frameworks (Adapted from Imenda, 2014, p. 189)

Theoretical frameworks

The frameworks presented in this work are rooted in the theoretical foundations of the main doctoral study for the first author, which are based on the constructivist theory of learning (CTL) and the social cognitive theory (SCT), which are both situated within Bandura's (1989) social learning theory (SLT). The study's conceptual framework, study objectives, and insights were integrated with the findings from the original doctoral research to developing PWIPF. This amalgamation resulted in a framework designed to support and enhance science practical work and inquiry-based instruction in Namibian science classrooms.

Constructivist theory of learning

CTL, emphasizing learners' active knowledge construction through experiences and interactions with their immediate environment, serves as the central theme of this study (Bada & Olusegun, 2015).

The key principles highlighted by CTL include a learner-centered approach, inquiry-based instruction, the teacher's role as a facilitator, knowledge construction and integration, as well as active learning, collaboration, and cooperation.

CTL underlined the significance of building on past knowledge and the learner's active participation in the learning process. The learner-centered approach is a fundamental concept in the constructivism philosophical thought of learning (Xu & Shi, 2018). In the constructivist classroom, learners were considered active participants in their own learning, creating questions, conducting investigations, and constructing new knowledge. It has been noted that, teachers take on the responsibilities of facilitators, classroom managers, and organizers in this approach for learning, fostering a congenial atmosphere, and adjusting instruction in accordance with the prior knowledge and comprehension levels of learners (Chuang, 2021; Shah, 2019).

Constructivism also emphasized the essence of inquiry-based instruction (Chu et al., 2021), which was the primary focus of this study. The study considered how constructivism's fundamental principles were aligned with inquiry-based instruction. For example, several researchers outlined that inquiry-based instruction encourages active learning, critical thinking, and problem-solving abilities in learners by means of supporting them to undertake investigations, ask questions, while searching for answers through such investigations and observations (Chu et al., 2021; Gholam, 2019; Ješková et al., 2022; Ramadani et al., 2021). The importance of a teacher's facilitation of knowledge acquisition in constructivist classrooms has been highlighted throughout this study. In order to meet the requirements of learners and encourage collaborative and cooperative learning, teachers foster a supportive environment, promote learners' participation in investigations, and provide guidance and criticism to learners (Jacobs & Renandya, 2019; van Leeuwen & Janssen, 2019; Warsah et al., 2021).

Other significant issues emphasised throughout the study are knowledge integration and construction. Constructivism considers learning as a process that draws on prior knowledge and experiences in which learners are expected to connect concepts and accommodate new information into their existing schema (Saunders & Wong, 2020; Suhendi et al., 2021). The current study explored how learners organize and reorganize their cognitive processes to create new meaning through inquiry-based learning process. Other themes highlighted in this study as essential elements of constructivist classrooms in which learners' interests and inquiries are at the center of the learning process, include active, collaborative, and cooperative learning. Individual work, pair work, group activities, collaborative conversations, and interactive experiences are used to facilitate learning and knowledge construction in this regard (Menekse & Chi, 2019).

Social cognitive theory

As previously discussed, Bandura's (1989) SLT established the groundwork for SCT. This theory elucidates the process of learning, emphasizing knowledge acquisition through observation and imitation of others, particularly by modeling their behavior or being influenced by their behaviors. For instance, a learner acquires knowledge by observing and imitating the actions of a teacher (Koutroubas & Galanakis, 2022). SCT describes how people create a cognitive construct after observing an event, which then influences how they will behave in the future (Schunk & DiBenedetto, 2020) (Devi et al., 2017). In the context of this research, educators are deemed to employ instructional methods based on their own learning experiences as students. SCT posits that individuals acquire knowledge by observing and emulating the actions and non-actions of others, emphasizing the significance of these processes in understanding personality (Bandura, 1989, 2014). The individual person (and hence cognition) is just as crucial in shaping moral development, according to social cognitists, who acknowledge that acquired conduct demonstrated in one's upbringing has a significant degree of influence on development (Devi et al., 2022). SCT thus posits that individuals acquire knowledge by observing and emulating the actions and non-actions of others, emphasizing the significance of these processes in understanding personality.

This research study adopts SCT as its theoretical framework, as SCT posits that individuals acquire knowledge through observational learning. In the context of this study, teachers are deemed to employ instructional methods based on their own learning experiences as learners. Development is influenced by the interplay of environment, behavior, and cognition, forming a dynamic process known as triadic

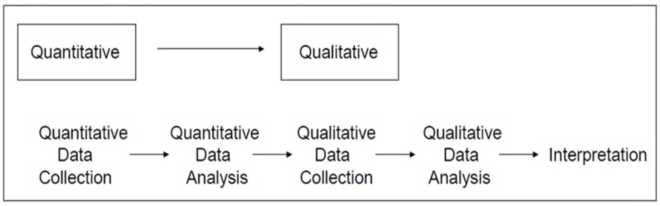

Figure 4. A sequential explanatory mixed methods design (Terrell, 2012)

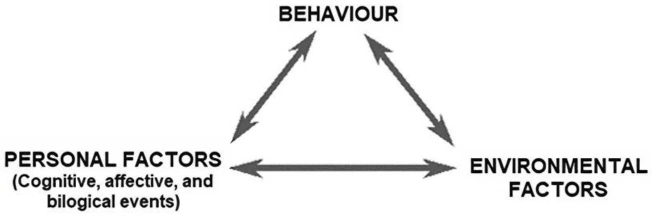

Figure 3. Three factors of SCT (Pajares, 2002)

reciprocal determinism. This perspective rejects the notion of learners as static or isolated entities (Bandura, 1989, 2014). This study contextualizes SCT by emphasizing that learners acquire knowledge directly from various sources, such as social interactions, experiences, and external media influences (Ifinedo, 2017; Schunk & DiBenedetto, 2020). The theory underscores the significance of imitating others' behavior for human survival, leading to the designation of teachers as exemplary role models in this research. The study asserts that learning new behaviors involves more than mere attempts and outcomes; hence, the theory is employed to explore how an understanding of human influence impacts both the environment and individuals. Additionally, the study applies the theory to clarify the role of observational learning within SCT, highlighting how individuals can gain insights into both positive and negative behaviors through observation. It is important to note that learning does not always translate into behavioral change.

A key concept in SCT and self-efficacy is vicarious learning, which is the process of learning from other people's actions (Beauchamp et al., 2019; Devi et al., 2017; Harinie et al., 2017). According to this theory, learners can copy other people's behavior after watching them in action, and as a result people avoid making mistakes and may carry out actions better if they witness others successfully carry them out (Beauchamp et al., 2019). There are four ways of boosting self-efficacy (Beauchamp et al., 2019), one of such ways is social modelling, which includes vicarious learning. Social modeling encompasses the processes of observing behavior, receiving demonstrations, and receiving guidance on the execution of certain actions (Schlüter et al., 2017; Schunk & DiBenedetto, 2020). Additionally, there are three other strategies: verbal persuasion, manipulation of physical and emotional states, and mastery experience (Schlüter et al., 2017). Mastery experience involves a therapeutic or interventionist approach to assisting individuals in achieving small, attainable objectives. According to SCT, a theory of learning, behavior is influenced not only by the environment in which an individual is raised but also by the individual themselves, emphasizing the importance of cognition (Beauchamp et al., 2019). This study utilized the notion that the environment, behavior, and cognition serve as the main components that influence development in a reciprocal triadic interaction, and people learn by watching others. According to the theory, every action that is observed has the power to alter someone's perspective (cognition). Similarly, one's upbringing might affect their behavior in the learning process.

In pursuit of this objective, Bandura (2014) simplifies the core concepts of the theory through the conceptualization of triadic reciprocal causation. The framework employed in this research is situated within a specific context, illustrating how fostering confidence in a learner's ability to execute a task effectively influences the learner's capacity to reproduce an observed activity. The three elements of SCT, as outlined in this section, are illustrated in **Figure 3**, following the interpretation proposed by Pajares (2002).

RESEARCH DESIGN

Methods

This study is guided by the mixed methods approach (Hitchcock & Onwuegbuzie, 2020; Tashakkori & Teddlie, 2021), whereby quantitative data have been collected and analyzed followed by the collection and analysis of the qualitative data. A mixed methods approach combines the techniques and methods from both the quantitative (portraying a positivism paradigm) and qualitative (which is by virtue of being, portrays a constructivist or an interpretivist paradigm) in a single study (Hitchcock & Onwuegbuzie, 2020, 2022; Tashakkori & Teddlie, 2021). Within a mixed methods approach, data from both quantitative and qualitative are collected and analyzed within a single study to help understand a research problem in depth (Creswell & Creswell, 2017; Hitchcock & Onwuegbuzie, 2022; Plano Clark, 2017). The research design for this study was a sequential explanatory mixed method (Creswell & Creswell, 2017), where quantitative data in a form of a questionnaire survey was collected and analyzed followed by the collection and analysis of qualitative data in the form of classroom observations, structured interviews and document analysis. **Figure 4** illustrates a sequential explanatory mixed methods design comprising five interconnected stages. These stages encompass quantitative data collection, quantitative data analysis, qualitative data collection, qualitative data analysis, and the subsequent interpretation phase.

Participants & Data Collection Methods

The initial phase of data collection, the online questionnaire survey was completed by 130 teachers who either taught physical science (grade 8 and grade 9) and/or physics or chemistry (grades 10 to 12) across all 14 educational regions in Namibia. These teachers were randomly selected from all the teachers who taught the science subject as presented earlier. The second phase of data collection encompassed the collection of qualitative data by means of classroom observations, teacher interviews and document analysis to establish explanations and clarifications for the previously established quantitative findings from the initial stage. In entirety, a sample of 10 teachers was purposefully selected from a pool of 130 teacher who successfully responded to an online questionnaire survey. The inclusion of teachers in this phase was determined by the first author's accessibility to them. To facilitate this, an observation schedule devised by the researchers was employed, encompassing the actions and elements involved in executing science practical activities. The schedule comprised predefined criteria, which the researcher marked off while observing teachers conducting a science lesson while engaging in a practical demonstration or activity with learners. The first author conducted on-site visits to observe teachers implementing inquiry-based instruction during science practical work in their classrooms at their respective schools.

For qualitative data collection particularly, the selection of teachers was purposeful and guided by specific criteria related to their characteristics. These criteria encompassed gender sensitivity, ensuring a balanced representation of both males and females in the interview pool. Additionally, teachers of various age groups were included, representing different generational perspectives. The selection process also considered the diverse school locations of the participants, encompassing those in rural, semi-rural, and urban settings. The positions held by the teachers within schools, such as classroom/subject teachers and heads of departments, were also considered. Furthermore, the chosen teachers were selected based on their availability at a specific time, their expressed interest in participating, and their prior experience in teaching various aspects of the curriculum. This included teaching physical science in grade 8 and grade 9 under the revised curriculum, as well as teaching physical science in grade 8-grade 10 under the old curriculum. Additionally, the teachers had experience teaching physical science grade 11-grade 12 under the legacy curriculum, and/or physics and chemistry in grade 10-grade 12 under the revised curriculum.

The final stage of data collection during this study involved analyzing documents pertaining to the teaching of science in Namibian schools. Documents such as the national curriculum for basic education, the national subject policy guide for physical science, physics, and chemistry grade 8-grade 12, the physical science grade 8 and grade 9, chemistry & physics grade 10-grade 11 syllabuses, the report on the examinations (from 2019 to 2022), national professional standard for teachers in Namibia, the national promotion policy guide for junior and senior secondary school phases, and the learning support teachers' manual were analyzed to evaluate the integration and support of inquiry-based instruction. Document analysis, an underutilized qualitative research method, was employed for this purpose, recognizing its value and application in analyzing existing textual materials (Morgan, 2022). This approach is particularly beneficial when constraints such as limited resources or time hinder field research, and it also addresses ethical concerns associated with other qualitative methods (Morgan, 2022; Tracy, 2019). Drawing insights from diverse data sources, including questionnaires, classroom observations, interviews, and document analysis, a PWIPF has been devised to enhance the implementation of science practical work in Namibian schools.

Data Analysis

As data was collected in different steps during the study, data analysis aligned well with such steps. In the first step of the research, quantitative data collected through an online questionnaire survey with Namibian science teachers were analyzed using statistical packages for social sciences (IBM SPSS-PASW version 27). The data underwent initial processing in an Excel spreadsheet, involving cleaning and validation based on the completeness and correctness of respondent answers. Descriptive statistics, including standard deviation, mean, frequencies, and percentages, were calculated to determine Namibian science teachers' conceptions. The mean values were obtained using IBM SPSS-PASW version 27, and the results were presented through tables and figures. The subsequent steps involved qualitative data analysis from classroom observations, audio-recorded and transcribed teacher interviews, and document analysis. Thematic analysis, as described by Dawadi (2021) and Sundler et al. (2019), was employed to systematically organize and interpret patterns of meaning in the data, confirming findings from the quantitative survey. Thematic analysis, described as a theoretically informed and structured qualitative research method, was guided by a framework presented by Sundler et al. (2019) in the current study.

Following an analysis of both quantitative (derived from a questionnaire survey involving 130 science teachers in Namibia) and qualitative data (obtained through classroom observations and interviews with 10 teachers conducting science practical activities), as well as document analysis, the researchers employed exploratory factor analysis (EFA). According to Reio Jr and Shuck (2015), EFA is a statistical tool utilized in research to examine relationships among individual variables and identify latent factors within measured variables. In simpler terms, EFA is employed to explore observed factors (known) and uncover latent ones (unknown) that stem from the known factors (Knekta et al., 2019; Ledesma et al., 2021). It is utilized to identify the k latent factors that best describe j variables within a larger set of latent data, serving as an exploratory tool for developing testable concepts. Factor analysis, as affirmed by Reio Jr and Shuck (2015), is considered a valuable method for examining the internal structure of a group of variables or indicators. Latent constructs or factors are thought to elucidate and summarize responses to observed variables, aiding in the development of conceptual frameworks. In the context of this study, EFA was employed to identify latent variables concerning teachers' conceptions of science practical work using inquiry-based instructions, contributing to the formulation of PWIPF as a framework to enhance science practical work in Namibian schools.

PRACTICAL WORK INQUIRY PRACTICE FRAMEWORK

PWIPF, which resulted from the objectives of the first author's study is designed to enhance the classroom practices of Namibian science teachers in implementing inquiry-based instruction in science practical work. The framework outlines its components across three levels: macro, meso, and micro. This development aligns with the principles advocated by Fanghanel et al. (2016), who, in their study, introduced an audit and capacity-building tool to advance the scholarship of teaching and learning. According to their philosophy, it is

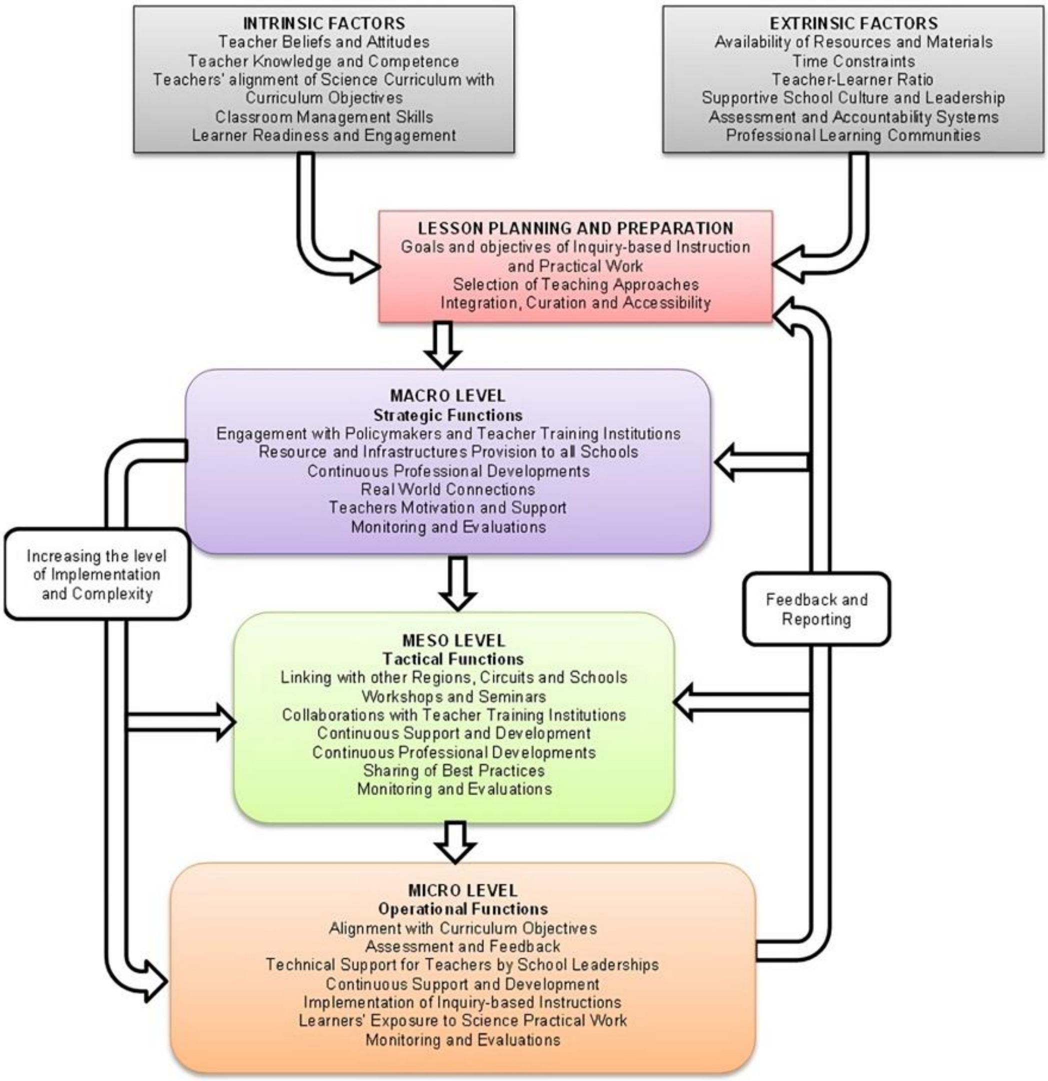

Figure 5. PWIPF (Source: Author)

necessary to identify and define various actions, roles, responsibilities, and activities of individuals during the implementation process.

Furthermore, the formation of this framework, emphasizing the roles of diverse stakeholders in enhancing learners' academic performance in Namibian science classrooms, was influenced by 'national standards and performance indicators for schools in Namibia' (MoE, 2005). These standard highlights efforts to improve teaching conditions and services in Namibian schools. This national curriculum document outlines seven key areas and performance indicators as plans of action for academic improvement in Namibian schools. Specifically relevant to this study, in terms of advancing the implementation of science practical work, are key areas such as 'the provision of resources to schools and hostels' (key area one), 'curriculum and attainment' (key area two), the 'teaching and learning process' (key area three), 'management and leadership of the school' (key area five), and 'links with other schools and the region' (key area seven). Thus, the development of PWIPF, aligned well these key areas and performance indicators for improving science education in Namibian schools.

Figure 5 illustrates PWIPF. Within this framework, lesson planning and preparation, which are pivotal in teaching and learning are significantly influenced by teachers' conceptions, including intrinsic and extrinsic factors, which serve as the framework's basis. Intrinsic factors of teachers involve considerations such as their beliefs, behaviors, attitudes, knowledge, competency, and actions aligning teaching with science curriculum documents (i.e., science subjects syllabuses) and specific subject objectives. Furthermore, teachers' intrinsic factors encompass classroom management skills, learners' readiness, and engagement in science practical activities, all influencing the inclusion of inquiry-based instruction in science practical work during lesson planning and preparation.

Teachers' extrinsic factors involve considerations such as the availability of resources for science practical work, timetabling for teaching or extracurricular activities, and the restructuring of existing staffing norms, like the teacher-learner ratio, to support smaller class sizes. Socio-anthropological and educational structures and policies also contribute to teachers' extrinsic factors. Additionally, the teacher's school support system, culture, leadership, assessment and accountability systems, and participation in continuous professional development (CPD) activities are all interconnected components influencing teachers' extrinsic factors and, consequently, shaping their teaching practices.

For this study, the macro level is defined by the balancing of science subject content, which entails collaboration with the government through the Ministry of Education, Arts and Culture (MoEAC), engagement with stakeholders, and training programs for teachers. At this level, interaction with educational policymakers, allocation of resources to all schools (highlighted as key area number one) and providing CPD for science teachers regarding the implementation of practical work and inquiry-based instruction are integral components. Moreover, to facilitate the integration of inquiry-based instruction in science practical work within Namibian schools, this level actively seeks to draw upon real-world best practices and establish partnerships with other countries. Ensuring teacher motivation and implementing effective monitoring and evaluation mechanisms are crucial aspects of facilitating the implementation process at the macro level.

Meso level, focusing on enhancing science teachers' instructional practices in Namibia, is anchored in the organization of science subject topics or structures to be taught at the school, circuit, or regional level during a specific semester or year. Various stakeholders play pivotal roles in advancing the teaching of science practical work in Namibian schools, including fostering connections with other educational institutions at the school, circuit, and regional levels (highlighted as key area number seven). This involves the exchange of best practices in implementing inquiry-based instruction, conducting workshops and seminars for teachers on teaching science practical work, and fostering collaborations with teacher training institutions. Continuous support, professional development, and the establishment of a resilient monitoring and assessment framework processes are fundamental components of the meso level.

The micro level represents the final stage in the implementation process of inquiry-based science practical work in Namibian schools. This crucial phase involves teachers' interpretations and aligning with curriculum objectives, assessment of learners' investigative and experimental skills (objective C as per the science syllabuses in Namibia), and the provision of feedback to the upper levels regarding the progress of inquiry implementation and CPD. Additionally, the technical support provided by school leaderships (key area 5) plays a reflective role in enhancing the implementation of inquiry-based instruction (key area 2 and key area 3) to improve science practical work in Namibian schools. Within the context of this study and its framework aimed at enhancing science teaching, factors such as teachers' and learners' subject knowledge, classroom interactions, and various science practical activities (e.g., learner-orchestrated demonstrations, investigations, and experiments) contribute to the improvement of science practical work.

As a result, the framework integrates a holistic number of activities such as planning, teachers' professional development, curriculum design, resource development, classroom implementation, assessment and feedback, collaboration, community engagement, monitoring and evaluation, continuous support and development, stakeholders' engagement, intrinsic and extrinsic factors influencing teachers, resource provision to schools, supportive school culture and leadership, teacher support, learner diversity and engagement, community involvement, and technology and internet connectivity. All these elements are interconnected within the framework to facilitate and support teachers in implementing science practical work through inquiry-based instruction in Namibian schools. The study findings highlighted a disparity between teachers' conceptions of science practical work and the implementation of inquiry-based instructions, prompting the framework to propose specific factors that should be addressed at macro, meso, and micro levels to bridge the identified gap.

The subsequent sections, unpack the main components of PWIPF encompassing factors intrinsic and extrinsic to teachers (behaviors), planning, professional development, curriculum design, and resource development. Additionally, the discussion includes assessment and feedback, collaboration, community engagement, monitoring and evaluation, science practical work and inquiry-based instruction classroom implementation, ongoing support and development, engagement of stakeholders, and the establishment of professional learning communities to enhance the practices of science teachers.

Planning

As depicted in **Figure 5**, planning constitutes the initial phase in introducing inquiry-based instructional methods into science practical work within Namibian science classrooms. This planning stage necessitates a clear definition of the objectives and goals associated with inquiry-based instruction in science education. These objectives should address the frequency of science practical activities, aligning them with the content outlined in the science subject syllabuses. Moreover, the planned activities should agree with the broader goals and objectives of the national science curriculum, as well as the specified assessment objectives as outlined in the science subject syllabuses. Thus, planning assumes a pivotal role across all levels of inquiry-based science instruction.

Professional Development

Concerning professional development, the enhancement of teachers' capabilities should primarily occur at the meso and micro levels. This requires the provision of extensive professional development opportunities tailored for science teachers to be involved in implementing science practical work within their classrooms. The onus falls on the government to supply teachers with professional development opportunities related to inquiry-based instruction and science practical work, particularly for in-service teachers. This can be achieved through initiatives such as workshops, seminars, interventions, and collaborative learning experiences. These platforms aim to supplement in-service teachers' skills, capabilities, and comprehension of inquiry-based instruction. Additionally, they serve to keep in-service teachers continuously informed about contemporary trends in science education, specifically in science practical activities. Simultaneously, teacher training institutions bear the responsibility of equipping pre-service teachers with the necessary training in implementing inquiry-based teaching methods, the facilitation of science practical work, effective questioning techniques, and design of inquiry-based lessons.

Curriculum Design & Resource Development

Through ongoing assessments, the revision of the current science curriculum in Namibia is imperative to integrate inquiry-based methodologies for the realization of a learner-centered approach, a concept acknowledged by various educational stakeholders but yet to be fully realised. The development of curriculum resources should contribute to establishing a repository of inquiry-based science activities, experiments, and investigations tailored for Namibian secondary schools. It is essential to ensure that this resource bank aligns with the expectations of the science curriculum and is readily accessible to all science teachers in Namibia.

Classroom Implementation

Despite the potential influence of individuals at the macro and meso levels of inquiry, it is crucial to involve teachers at the grassroots level in this process. Teachers should be motivated to formulate and design inquiry-based lessons that foster learners' curiosity, critical thinking, and problem-solving abilities. Offering guidance on scaffolding inquiry-based activities to cater to the diverse needs of learners is essential. Furthermore, supporting teachers in creating a secure and encouraging classroom environment that promotes learner engagement, collaboration, and exploration is paramount. This intervention primarily operates at the micro level of inquiry, complemented by the roles of stakeholders at the macro and meso levels.

If implemented, this framework is envisaged to cause improvement and changes in the Namibian science classrooms in terms of exposing and giving autonomy to learners and exposing them to investigative and experimental skills as proposed in the science curriculum documents for Namibian schools. The involvement and engagement of all stakeholders at all levels of implementation will lead into shared experiences and best practices of improving science performance in Namibian schools. As it is the proposition of the researchers that the level of implementation complexity is increasing from the macro through the meso into the micro level, teachers, and learners at the highest level of inquiry implementation need continuous support and engagement will all parts involved.

DISCUSSION

The research aimed to investigate the potential impact of implementing PWIPF on the academic performance of science learners, specifically in terms of investigative and experimental activities in science classrooms. This study is particularly relevant as it addresses the need for effective methodologies in science education, a critical aspect of nurturing scientific inquiry skills among learners. The research suggests that the successful implementation of PWIPF is likely to lead to a significant increase in the academic performance of science learners. For example, a study by Jerrim et al. (2022) found that there exists a relationship between learners' performance and their involvement in inquiry-based teaching and learning. By unpacking and applying this framework, science teachers are envisaged to develop an environment that fosters inquiry-based learning, enabling learners to actively engage in the scientific method (Ambarita et al., 2019; Kibga et al., 2022). This shift towards a more hands-on and analytical approach has the potential to enhance understanding, critical thinking, and problem-solving skills among learners. The findings imply that a well-structured framework can serve as a catalyst for positive changes in the learning outcomes associated with practical work in science education.

The study's focus on a Namibian perspective adds an important dimension to the research. Namibia, like many other African nations, has a unique educational context shaped by cultural, social, and economic factors (Biraimah, 2016; Shilongo, 2017). The implementation of the framework within this specific context not only speaks to its adaptability but also underscores the importance of considering local intricacies in educational practices. The research suggests that tailoring instructional strategies to the cultural context of Namibia can enhance the effectiveness of science education, making it more accessible and meaningful for learners.

The positive correlation between PWIPF and increased academic performance in investigative work implies a potential avenue for educational reform. As countries strive to improve their education systems, incorporating inquiry-based methodologies may be a crucial step in fostering a generation of scientifically literate individuals (Davis, 2022). The findings of this study could influence educational policies and practices, encouraging a shift towards more learner-centered and experiential learning approaches, not only in Namibia but potentially in other contexts as well.

The study opens possibilities for future research by highlighting the need for continued exploration of effective teaching frameworks in science education. Further investigations could delve into the long-term impact of implementing PWIPF, considering factors such as sustained academic performance, learner engagement, and the development of lifelong inquiry skills. Additionally, the findings may stimulate discussions on teacher training programs, curriculum development, and the allocation of resources to support the successful integration of such frameworks within diverse educational systems.

The literature review has highlighted the pivotal role of practical work in science education, emphasizing its ability to engage learners actively through hands-on experiences and real-world interactions (Yannier et al., 2020). Studies have shown that such activities not only enhance learners' understanding of scientific concepts but also develop critical thinking and problem-solving skills (Lee & Sulaiman, 2018; Sshana & Abulibdeh, 2020). However, despite the recognized benefits, the implementation of practical work in science education faces numerous challenges, including limited resources, inadequate teacher training, and varying levels of student engagement (Akuma & Gaigher, 2021; Wei et al., 2019). The review underscores the need for a structured framework that can address these challenges and optimize the effectiveness of practical work in fostering scientific inquiry and learning.

This study aimed to addressing these gaps by proposing a comprehensive framework tailored to the Namibian educational context. By incorporating insights from the literature, this study explores how a well-defined framework can enhance the accomplishment of practical work and promote inquiry-based learning. The framework emphasizes the integration of real-world applications, collaborative learning, and the systematic collection and analysis of data, aligning with the principles outlined by the National Research Council (2012). The study's findings provide empirical evidence on the effectiveness of this approach, highlighting improvements in learner engagement, knowledge, and the overall quality of science education in Namibia.

These discussions of the results are indicative of how the implementation of PWIPF is espoused to lead to significant advancements in the way science practical work is envisaged to be conducted in Namibian schools. It is hoped that with the successful implementation and enactment of this framework, teachers are expected to report an increase in their confidence and competence in facilitating practical activities, while learners will demonstrate greater enthusiasm and a deeper understanding of scientific concepts. Additionally, the framework's focus on inquiry-based learning is believed to foster a more investigative approach among learners, encouraging them to ask questions, conduct experiments, and draw conclusions independently. These expected outcomes suggest that the framework is not only meant to addressing the challenges identified in the literature but also offers a scalable model that can be adapted to other educational settings, thereby contributing to the broader goal of enhancing science education globally.

CONCLUSIONS

In conclusion, the investigation into PWIPF for enhancing science practical work and inquiry within the Namibian educational context has yielded significant insights. The study underlines the potential positive impact of implementing this framework, highlighting a promising correlation between its application and an anticipated improvement in science learners' academic performance, particularly in the field of science investigations and practical work. By unpacking the particulars of the framework, the research has illuminated its efficacy in fostering a conducive learning environment that encourages learner to engage actively in scientific inquiry. The identified positive association between the implementation of the framework and enhanced academic performance underscores its potential to serve as a valuable tool for teachers and policymakers seeking to elevate the quality of science education in Namibia.

Furthermore, the findings suggest that PWIPF aligns with the pedagogical needs and educational objectives within the Namibian educational landscape. This alignment emphasizes the framework's potential for successful integration into the existing science education curriculum, offering a tailored approach that resonates with the specific requirements of the local context. To this end, there is a need in for recognizing and embracing such pedagogical frameworks, as they contribute not only to the academic success of learner but also to the broader goal of fostering a generation of scientifically literate individuals. As Namibia continues to shape its educational policies and practices, the implications of this research encourage educational stakeholders to consider the meaningful adoption of PWIPF as a strategic means to elevate the quality and efficacy of science education in the country.

Recommendations

Based on the objectives and findings of this study the following are the three main recommendations that are emanating from this study:

1. The study highlights the potential positive impact of implementing this framework in Namibian schools to enhance science practical work and inquiry. Therefore, it is recommended that this framework be actively introduced and integrated into science education curricula across the country.
2. It is of utmost importance to support teacher training and professional development, since the success of the framework depends on how effectively it is implemented by teachers. Thus, MoEAC in Namibia in collaboration with stakeholders like teacher training institutions are encouraged to provide teachers with the necessary training and professional development opportunities. This could involve workshops, seminars, and ongoing support to ensure that both pre- and in-service teachers understand how to utilize framework effectively in their teaching practices.
3. As the framework is integrated into the Namibian science educational system, it's essential to continuously monitor and evaluate its effectiveness. This could involve collecting data on learners' academic performance in science investigations and practical work, as well as gathering feedback from teachers and learners about their experiences with the framework. This ongoing evaluation process will help to identify any areas for improvement and ensure that the framework is achieving its intended goals.

Funding: No external funding is received for this article.

Ethical statement: The author stated that the Ethical Committee of The International University of Management approved the study on 8 June 2022 (Approval code: 2022/06/08/50415034/04/AM) before collecting data for the study. Additionally, permission to conduct the research within the chosen group was acquired from the Ministry of Education, Arts, and Culture (MoEAC) in Namibia on 1 July 2022 (No: 13/2/9/1). The author further stated that every participant signed consent forms, guaranteeing their involvement in the study with assurances of confidentiality, anonymity, and the trustworthiness of their responses and diagnosis scores. Consequently, discussions and certifications addressed potential internal threats to validity and reliability.

Declaration of interest: The author declares that there are no competing interests.

Availability of data and materials: All data generated or analyzed during this study are available for sharing when appropriate request is directed to author.

REFERENCES

Akpan, J., Notar, C. E., & Beard, L. (2021). The impact of mnemonics as instructional tool. *Journal of Education and Human Development, 10*(3), 20-28. https://doi.org/10.15640/jehd.v10n3a3

Akuma, F. V., & Callaghan, R. (2019a). A systematic review characterizing and clarifying intrinsic teaching challenges linked to inquiry-based practical work. *Journal of Research in Science Teaching, 56*(5), 619-648. https://doi.org/10.1002/tea.21516

Akuma, F. V., & Callaghan, R. (2019b). Teaching practices linked to the implementation of inquiry-based practical work in certain science classrooms. *Journal of Research in Science Teaching, 56*(1), 64-90. https://doi.org/10.1002/tea.21469

Akuma, F. V., & Gaigher, E. (2021). A systematic review describing contextual teaching challenges associated with inquiry-based practical work in natural sciences education. *EURASIA Journal of Mathematics, Science and Technology Education, 17*(12), em2044. https://doi.org/10.29333/ejmste/11352

Ambarita, R. A., Yunastiti, Y., & Indriayu, M. (2019). The application of group investigation based on hands on activities to improve learning outcomes based on higher order thinking skills of students at SMA Negeri 2 Pematangsiantar. *Budapest International Research and Critics in Linguistics and Education Journal, 2*(2), 351-359. https://doi.org/10.33258/birle.v2i2.310

Bada, S. O., & Olusegun, S. (2015). Constructivism learning theory: A paradigm for teaching and learning. *Journal of Research & Method in Education, 5*(6), 66-70.

Bandura, A. (1989). Human agency in social cognitive theory. *American Psychologist, 44*(9), 1175. https://doi.org/10.1037//0003-066X.44.9.1175

Bandura, A. (2014). Social cognitive theory of moral thought and action. In W. M. Kurtines, & J. L. Gewirtz (Eds.), *Handbook of moral behavior and development* (pp. 69-128). Psychology Press.

Bao, L., & Koenig, K. (2019). Physics education research for 21st century learning. *Disciplinary and Interdisciplinary Science Education Research, 1*, 2. https://doi.org/10.1186/s43031-019-0007-8

Beauchamp, M. R., Crawford, K. L., & Jackson, B. (2019). Social cognitive theory and physical activity: Mechanisms of behavior change, critique, and legacy. *Psychology of Sport and Exercise, 42*, 110-117. https://doi.org/10.1016/j.psychsport.2018.11.009

Bilican, K., Senler, B., & Aydeniz, M. (2021). Facilitating inquiry-based learning during COVID-19 pandemic: Experiences of Turkish elementary science teachers. In Dr. V. L. Akerson, & I. S. Carter (Eds.), *Science education during the COVID-19 pandemic: Tales from the front lines* (pp. 63-90). ISTES.

Biraimah, K. L. (2016). Moving beyond a destructive past to a decolonised and inclusive future: The role of ubuntu-style education in providing culturally relevant pedagogy for Namibia. *International Review of Education, 62*, 45-62. https://doi.org/10.1007/s11159-016-9541-1

Bugingo, J. B., Yadav, L. L., Mugisha, I. S., & Mashood, K. (2022). Improving teachers' and students' views on nature of science through active instructional approaches: A review of the literature. *Science & Education, 33*(2), 1-43. https://doi.org/10.1007/s11191-022-00382-8

Byrd, V. L., & Asunda, P. A. (2020). Using evidence based practices and learning to enhance critical thinking skills in students through data visualization. In *Proceedings of the 2020 IEEE Frontiers in Education Conference*. IEEE. https://doi.org/10.1109/FIE44824.2020.9274157

Caena, F., & Redecker, C. (2019). Aligning teacher competence frameworks to 21st century challenges: The case for the European digital competence framework for educators (Digcompedu). *European Journal of Education, 54*(3), 356-369. https://doi.org/10.1111/ejed.12345

Cairns, D., & Areepattamannil, S. (2019). Exploring the relations of inquiry-based teaching to science achievement and dispositions in 54 countries. *Research in Science Education, 49*(1), 1-23. https://doi.org/10.1007/s11165-017-9639-x

Cakiroglu, U., Guven, O., & Saylan, E. (2020). Flipping the experimentation process: Influences on science process skills. *Educational Technology Research and Development, 68*(6), 3425-3448. https://doi.org/10.1007/s11423-020-09830-0

Chikaluma, P. H., Opanga, D., & Nsengimana, V. (2022). Contribution of inquiry-based learning to the improvement of biology teaching and learning. *The International Journal of Science, Mathematics and Technology Learning, 29*(2), 29. https://doi.org/10.18848/2327-7971/CGP/v29i02/29-52

Chu, S. K. W., Reynolds, R. B., Tavares, N. J., Notari, M., & Lee, C. W. Y. (2021). *21st century skills development through inquiry-based learning from theory to practice*. Springer.

Chuang, S. (2021). The applications of constructivist learning theory and social learning theory on adult continuous development. *Performance Improvement, 60*(3), 6-14. https://doi.org/10.1002/pfi.21963

Constantinou, M., & Fotou, N. (2020). The effectiveness of a must-have practical work in tertiary life science education. *Information, 11*(9), 401. https://doi.org/10.3390/info11090401

Creswell, J. W., & Creswell, J. D. (2017). *Research design: Qualitative, quantitative, and mixed methods approaches*. SAGE.

Davis, L. E. (2022). *Inquiry-based teaching and learning as a tool for achieving a scientifically literate future: Combating a post-truth world* [Master's thesis, Western Michigan University].

Dawadi, S. (2021). Thematic analysis approach: A step by step guide for ELT research practitioners. *Journal of NELTA, 25*(1-2), 62-71. https://doi.org/10.3126/nelta.v25i1-2.49731

de Jong, T. (2019). Moving towards engaged learning in STEM domains; there is no simple answer, but clearly a road ahead. *Journal of Computer Assisted Learning, 35*(2), 153-167. https://doi.org/10.1111/jcal.12337

Devi, B., Khandelwal, B., & Das, M. (2017). Application of Bandura's social cognitive theory in the technology enhanced blended learning environment. *International Journal of Applied Research, 3*(1), 721-724.

Devi, B., Pradhan, S., Giri, D., & Baxodirovna, N. L. (2022). Concept of social cognitive theory and its application in the field of medical and nursing education: Framework to guide research. *Journal of Positive School Psychology, 6*(4), 5161-5168.

Duncan, R. G., Na'ama, Y., & Chinn, C. A. (2021). Inquiry and learning in science. In R. G. Duncan, & C. Chinn (Eds.), *International handbook of inquiry and learning* (pp. 325-344). Routledge. https://doi.org/10.4324/9781315685779-22

Elesio, J. M. (2023). Science laboratory environment and attitude towards chemistry lessons of senior high school students. *East Asian Journal of Multidisciplinary Research, 2*(2), 839-850. https://doi.org/10.55927/eajmr.v2i2.3027

Fanghanel, J., Pritchard, J., Potter, J., & Wisker, G. (2016). Defining and supporting the scholarship of teaching and learning (SoTL): A sector-wide study. *AdvanceHE*. https://www.advance-he.ac.uk/knowledge-hub/defining-and-supporting-scholarship-teaching-and-learning-sotl-sector-wide-study

Fauth, B., Decristan, J., Decker, A.-T., Büttner, G., Hardy, I., Klieme, E., & Kunter, M. (2019). The effects of teacher competence on student outcomes in elementary science education: The mediating role of teaching quality. *Teaching and Teacher Education, 86*, 102882. https://doi.org/10.1016/j.tate.2019.102882

Fitzgerald, M., Danaia, L., & McKinnon, D. H. (2019). Barriers inhibiting inquiry-based science teaching and potential solutions: Perceptions of positively inclined early adopters. *Research in Science Education, 49*, 543-566. https://doi.org/10.1007/s11165-017-9623-5

Gericke, N., Högström, P., & Wallin, J. (2023). A systematic review of research on laboratory work in secondary school. *Studies in Science Education, 59*(2), 245-285. https://doi.org/10.1080/03057267.2022.2090125

Gholam, A. P. (2019). Inquiry-based learning: Student teachers' challenges and perceptions. *Journal of Inquiry and Action in Education, 10*(2), 6.

González-Pérez, L. I., & Ramírez-Montoya, M. S. (2022). Components of Education 4.0 in 21st century skills frameworks: Systematic review. *Sustainability, 14*(3), 1493. https://doi.org/10.3390/su14031493

Grant, C., & Osanloo, A. (2014). Understanding, selecting, and integrating a theoretical framework in dissertation research: Creating the blueprint for your "house". *Administrative Issues Journal, 4*(2), 4. https://doi.org/10.5929/2014.4.2.9

Harinie, L. T., Sudiro, A., Rahayu, M., & Fatchan, A. (2017). Study of the Bandura's social cognitive learning theory for the entrepreneurship learning process. *Social Sciences, 6*(1), 1. https://doi.org/10.11648/j.ss.20170601.11

Hitchcock, J. H., & Onwuegbuzie, A. J. (2020). Developing mixed methods crossover analysis approaches. *Journal of Mixed Methods Research, 14*(1), 63-83. https://doi.org/10.1177/1558689819841782

Hitchcock, J. H., & Onwuegbuzie, A. J. (2022). *The Routledge handbook for advancing integration in mixed methods research*. Taylor & Francis. https://doi.org/10.4324/9780429432828

Idris, N., Talib, O., & Razali, F. (2022). Strategies in mastering science process skills in science experiments: A systematic literature review. *Jurnal Pendidikan IPA Indonesia* [*Indonesian Science Education Journal*], *11*(1), 155-170. https://doi.org/10.15294/jpii.v11i1.32969

Idris, R., Govindasamy, P., Nachiappan, S., & Bacotang, J. (2023). Revolutionizing STEM education: Unleashing the potential of STEM interest career in Malaysia. *International Journal of Academic Research in Business and Social Sciences, 13*(7), 1741-1752. https://doi.org/10.6007/IJARBSS/v13-i7/17608

Ifinedo, P. (2017). Examining students' intention to continue using blogs for learning: Perspectives from technology acceptance, motivational, and social-cognitive frameworks. *Computers in Human Behavior, 72*, 189-199. https://doi.org/10.1016/j.chb.2016.12.049

Imaduddin, M., & Zuhaida, A. (2019). STREAMIN model for the next generation of science education in Indonesia. *Journal of Physics: Conference Series, 1233*, 012096. https://doi.org/10.1088/1742-6596/1233/1/012096

Imenda, S. (2014). Is there a conceptual difference between theoretical and conceptual frameworks. *Journal of Social Sciences, 38*(2), 185-195. https://doi.org/10.1080/09718923.2014.11893249

Jacobs, G. M., & Renandya, W. A. (2019). *Student centered cooperative learning: Linking concepts in education to promote student learning*. Springer. https://doi.org/10.1007/978-981-13-7213-1

Jassim, D. (2022). *The effect of language framework planning strategy for supporting the functions of language in the classroom* [Master's thesis, Karabuk University].

Jayawardena, P. R., van Kraayenoord, C. E., & Carroll, A. (2020). Factors that influence senior secondary school students' science learning. *International Journal of Educational Research, 100*, 101523. https://doi.org/10.1016/j.ijer.2019.101523

Jerrim, J., Oliver, M., & Sims, S. (2022). The relationship between inquiry-based teaching and students' achievement. New evidence from a longitudinal PISA study in England. *Learning and Instruction, 80*, 101310. https://doi.org/10.1016/j.learninstruc.2020.101310

Ješková, Z., Lukáč, S., Šnajder, Ľ., Guniš, J., Klein, D., & Kireš, M. (2022). Active learning in STEM education with regard to the development of inquiry skills. *Education Sciences, 12*(10), 686. https://doi.org/10.3390/educsci12100686

Kaindume, A. N. (2018). *Factors limiting science teachers from engaging learners in practical work: A case study* [Master's thesis, University of South Africa].

Kiang, K. M., & Colanero, K. (2020). A Classics Reading approach to nurture epistemic insight in a multidisciplinary and higher education context. In T. W. Teo, A-L.Tan, & Y. S. Ong (Eds.), *Science education in the 21st century: Re-searching issues that matter from different lenses* (pp. 51-65). https://doi.org/10.1007/978-981-15-5155-0_4

Kibga, E. S., Sentongo, J., & Gakuba, E. (2022). Development of chemistry learners' problem-solving skills through hands-on instructional model. *Development, 11*(4), 2029-2038. https://doi.org/10.11591/ijere.v11i4.22688

Knekta, E., Runyon, C., & Eddy, S. (2019). One size doesn't fit all: Using factor analysis to gather validity evidence when using surveys in your research. *CBE–Life Sciences Education, 18*(1), rm1. https://doi.org/10.1187/cbe.18-04-0064

Koutroubas, V., & Galanakis, M. (2022). Bandura's social learning theory and its importance in the organizational psychology context. *Psychology, 12*(6), 315-322. https://doi.org/10.17265/2159-5542/2022.06.001

Ledesma, R. D., Ferrando, P. J., Trógolo, M. A., Poó, F. M., Tosi, J. D., & Castro, C. (2021). Exploratory factor analysis in transportation research: Current practices and recommendations. *Transportation Research Part F: Traffic Psychology and Behavior, 78*, 340-352. https://doi.org/10.1016/j.trf.2021.02.021

Lee, I., Grover, S., Martin, F., Pillai, S., & Malyn-Smith, J. (2020). Computational thinking from a disciplinary perspective: Integrating computational thinking in K-12 science, technology, engineering, and mathematics education. *Journal of Science Education and Technology, 29*(3B), 1-8. https://doi.org/10.1007/s10956-019-09803-w

Lee, M. C., & Sulaiman, F. (2018). The effectiveness of practical work in physics to improve students' academic performances. *People: International Journal of Social Sciences, 3*(3), 1404-1419. https://doi.org/10.20319/pijss.2018.33.14041419

Lisao, C., Kilag, O. K., Tamayo, J. M., Abella, J., Cañete, N., & Abendan, C. F. (2023). Reimagining science education in the Philippines: A systematic analysis of the 7E learning cycle model's efficacy. *Excellencia: International Multi-disciplinary Journal of Education, 1*(5), 100-111.

Liswaniso, L. J. (2019). *An investigation into the teaching of biology and physical science practical works in senior secondary schools in the Zambezi Region, Namibia*. University of Namibia.

Lucz, I., & Milner-Bolotin, M. (2022). Video making as a powerful tool in physics teacher education and in teaching and learning. *Journal of Physics: Conference Series, 2297*, 012026. https://doi.org/10.1088/1742-6596/2297/1/012026

Majeed, N., Mukhtar, M. A., & Ehsan, M. I. (2023). Theoretical and conceptual frameworks in social sciences and law: Meaning, functions and differences. *Pakistan Journal of Social Research, 5*(1), 147-156. https://doi.org/10.52567/pjsr.v5i01.1034

Manz, E., Lehrer, R., & Schauble, L. (2020). Rethinking the classroom science investigation. *Journal of Research in Science Teaching, 57*(7), 1148-1174. https://doi.org/10.1002/tea.21625

Menekse, M., & Chi, M. T. (2019). The role of collaborative interactions versus individual construction on students' learning of engineering concepts. *European Journal of Engineering Education, 44*(5), 702-725. https://doi.org/10.1080/03043797.2018.1538324

Mlipha, N. D. (2022). *Teachers' implementation of inquiry-based learning activities in life sciences classrooms* [Master's thesis, University of South Africa].

MoE. (2005). *The national standards and performance indicators for schools in Namibia*. Ministry of Education.

Mohammed, S. M., Amponsah, K. D., Ampadu, E., & Kumassah, E. K. (2020). Extent of implementation of inquiry-based science teaching and learning in Ghanaian junior high schools. *EURASIA Journal of Mathematics, Science and Technology Education, 16*(12), em1928. https://doi.org/10.29333/ejmste/9373

Morado, M. F., Melo, A. E., & Jarman, A. (2021). Learning by making: A framework to revisit practices in a constructionist learning environment. *British Journal of Educational Technology, 52*(3), 1093-1115. https://doi.org/10.1111/bjet.13083

Morgan, H. (2022). Conducting a qualitative document analysis. *The Qualitative Report, 27*(1), 64-77. https://doi.org/10.46743/2160-3715/2022.5044

Moullin, J. C., Dickson, K. S., Stadnick, N. A., Albers, B., Nilsen, P., Broder-Fingert, S., Mukasa, B., & Aarons, G. A. (2020). Ten recommendations for using implementation frameworks in research and practice. *Implementation Science Communications, 1*, 42. https://doi.org/10.1186/s43058-020-00023-7

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. National Academies Press.

Ndoro, M. C. (2017). *Learner performance in integrated science process skills and attitudes in hands-on practical work versus virtual practical work* [Master's thesis, University of Cape Town].

Ngozi, P. O. (2021). Enhancing science process skills acquisition in chemistry among secondary school Students through context-based learning. *Science Education International, 32*(4), 323-330. https://doi.org/10.33828/sei.v32.i4.7

Nicol, C., Gakuba, E., & Habinshuti, G. (2020). An overview of learning cycles in science Inquiry-based Instruction. *African Journal of Educational Studies in Mathematics and Sciences, 16*(2), 76-81. https://doi.org/10.4314/ajesms.v16i2.5

Nollmeyer, G. E., & Baldwin, K. A. (2022). *Inquiry-based learning: Definition, history, and frameworks*. Routledge. https://doi.org/10.4324/9780367198459-REPRW34-1

Ntawuhiganayo, F., & Nsanganwimana, F. (2022). Effects of laboratory practical activities on learners' academic achievement and attitude towards biology in selected secondary schools in Rwanda. *Journal of Research Innovation and Implications in Education, 6*(1), 244-252.

Okolie, U. C., Igwe, P. A., Mong, I. K., Nwosu, H. E., Kanu, C., & Ojemuyide, C. C. (2022). Enhancing students' critical thinking skills through engagement with innovative pedagogical practices in global south. *Higher Education Research & Development, 41*(4), 1184-1198. https://doi.org/10.1080/07294360.2021.1896482

Oliveira, A. W., Brown, A. O., Zhang, W. S., LeBrun, P., Eaton, L., & Yemen, S. (2021). Fostering creativity in science learning: The potential of open-ended student drawing. *Teaching and Teacher Education, 105*, 103416. https://doi.org/10.1016/j.tate.2021.103416

Ortiz-Revilla, J., Adúriz-Bravo, A., & Greca, I. M. (2020). A framework for epistemological discussion on integrated STEM education. *Science & Education, 29*(4), 857-880. https://doi.org/10.1007/s11191-020-00131-9

Ortiz-Revilla, J., Greca, I. M., & Arriassecq, I. (2022). A theoretical framework for integrated STEM education. *Science & Education, 31*(2), 383-404. https://doi.org/10.1007/s11191-021-00242-x

Pajares, F. (2002). *Overview of social cognitive theory and self-efficacy*. http://www.emory.edu.EDUCATION/mfp/eff.html

Plano Clark, V. L. (2017). Mixed methods research. *The Journal of Positive Psychology, 12*(3), 305-306. https://doi.org/10.1080/17439760.2016.1262619

Ramadani, A. S., Supardi, Z. A. I., & Hariyono, E. (2021). Profile of analytical thinking skills through inquiry-based learning in science subjects. *Studies in Learning and Teaching, 2*(3), 45-60. https://doi.org/10.46627/silet.v2i3.83

Recker, J. (2021). *Scientific research in information systems: A beginner's guide*. Springer. https://doi.org/10.1007/978-3-030-85436-2

Reio Jr, T. G., & Shuck, B. (2015). Exploratory factor analysis: Implications for theory, research, and practice. *Advances in Developing Human Resources, 17*(1), 12-25. https://doi.org/10.1177/1523422314559804

Rosen, D. (2019). Being in uncertainties: An inquiry-based model leveraging complexity in teaching-learning. *Northeast Journal of Complex Systems, 1*(1), 5. https://doi.org/10.22191/nejcs/vol1/iss1/5

Saad, A. (2020). Students' computational thinking skill through cooperative learning based on hands-on, inquiry-based, and student-centric learning approaches. *Universal Journal of Educational Research, 8*(1), 290-296. https://doi.org/10.13189/ujer.2020.080135

Saputro, A. D., Rohaeti, E., & Prodjosantoso, A. K. (2019). Using inquiry-based laboratory instruction to improve critical thinking and scientific process skills among preservice elementary teachers. *Eurasian Journal of Educational Research, 19*(80), 151-170. https://doi.org/10.14689/ejer.2019.80.8

Saunders, L., & Wong, M. A. (2020). *Learning theories: Understanding how people learn*. Instruction in Libraries and Information Centers. https://doi.org/10.21900/wd.12

Schlüter, M., Baeza, A., Dressler, G., Frank, K., Groeneveld, J., Jager, W., Janssen, M. A., McAllister, R. R., Müller, B., & Orach, K. (2017). A framework for mapping and comparing behavioral theories in models of social-ecological systems. *Ecological Economics, 131*, 21-35. https://doi.org/10.1016/j.ecolecon.2016.08.008

Schunk, D. H., & DiBenedetto, M. K. (2020). Motivation and social cognitive theory. *Contemporary Educational Psychology, 60*, 101832. https://doi.org/10.1016/j.cedpsych.2019.101832

Shah, R. K. (2019). Effective constructivist teaching learning in the classroom. *Shanlax International Journal of Education, 7*(4), 1-13. https://doi.org/10.34293/education.v7i4.600

Shikongo, K. K. (2022). *Physical science teachers' pedagogical knowledge and practices of inquiry method at three selected senior secondary school level, Khomas Education Region* [Master's thesis, University of Namibia].

Shilongo, E. (2017). *Factors that shape learner achievement in socially disadvantaged and rural contexts: A social realist study in two rural senior secondary schools in Omusati Region, Namibia* [Doctoral dissertation, Rhodes University].

Shinana, E. N. L. (2019). *Mobilising the indigenous practice of making Oshikundu using inquiry-based approach to support grade 8 life science teachers in mediating learning of enzymes* [Unpublished master's thesis]. Rhodes University.

Shivolo, T. (2018). *Teachers' pical orientations in grade 8 teacher-orchestrated chemistry practical demonstrations: A focus on Oshikoto Region, Namibia* [Masters' thesis, The University of Johannesburg].

Shivolo, T., & Ramnarain, U. (2020). An investigation of the pedagogical orientations of grade 8 chemistry teachers in orchestrating practical demonstrations at schools in Oshikoto Region, Namibia. *Reform Forum, Journal for Educational Reform in Namibia, 28*(1), 44-58.

Spaan, W., Oostdam, R., Schuitema, J., & Pijls, M. (2022). Analysing teacher behavior in synthesizing hands-on and minds-on during practical work. *Research in Science & Technological Education, 42*(6), 1-18. https://doi.org/10.1080/02635143.2022.2098265

Ssempala, F. (2020). Relationship between chemistry teachers' nature of science epistemological views and the nature of inquiry-based instruction implemented in their classrooms in Uganda. *International Journal of Educational Policy Research and Review, 7*(3), 57-63.

Sshana, Z., & Abulibdeh, E. S. (2020). Science practical work and its impact on high students' academic achievement. *JOTSE, 10*(2), 199-215. https://doi.org/10.3926/jotse.888

Suhendi, A., Purwarno, P., & Chairani, S. (2021). Constructivism-based teaching and learning in Indonesian education. In *Proceedings of the Annual International Conference on Language and Literature* (pp. 76-89). KnE Social Sciences. https://doi.org/10.18502/kss.v5i4.8668

Sundler, A. J., Lindberg, E., Nilsson, C., & Palmér, L. (2019). Qualitative thematic analysis based on descriptive phenomenology. *Nursing Open, 6*(3), 733-739. https://doi.org/10.1002/nop2.275

Tal, T., Levin-Peled, R., & Levy, K. S. (2019). Teacher views on inquiry-based learning: The contribution of diverse experiences in the outdoor environment. *Innovation and Education, 1*, 2. https://doi.org/10.1186/s42862-019-0004-y

Tashakkori, A., & Teddlie, C. (2021). *SAGE handbook of mixed methods in social & behavioral research*. SAGE.

Tembrevilla, G., & Milner-Bolotin, M. (2019). Engaging physics teacher-candidates in the production of science demonstration videos. *Physics Education, 54*(2), 025008. https://doi.org/10.1088/1361-6552/aaf95d

Terrell, S. R. (2012). Mixed-methods research methodologies. *Qualitative Report, 17*(1), 254-280.

Thibaut, L., Knipprath, H., Dehaene, W., & Depaepe, F. (2019). Teachers' attitudes toward teaching integrated STEM: The impact of personal background characteristics and school context. *International Journal of Science and Mathematics Education, 17*(5), 987-1007. https://doi.org/10.1007/s10763-018-9898-7

Tracy, S. J. (2019). *Qualitative research methods: Collecting evidence, crafting analysis, communicating impact*. John Wiley & Sons.

Tsakeni, M. (2022). STEM education practical work in remote classrooms: Prospects and future directions in the post-pandemic era. *Journal of Culture and Values in Education, 5*(1), 144-167. https://doi.org/10.46303/jcve.2022.11

Twahirwa, J., & Twizeyimana, E. (2020). Effectiveness of practical work in physics on academic performance among learners at the selected secondary school in Rwanda. *African Journal of Educational Studies in Mathematics and Sciences, 16*(2), 97-108. https://doi.org/10.4314/ajesms.v16i2.7

Van Graan, D. C. (2020). *Exploring inquiry-based education in a professional learning program for science teachers* [Master's thesis, Stellenbosch University].

van Leeuwen, A., & Janssen, J. (2019). A systematic review of teacher guidance during collaborative learning in primary and secondary education. *Educational Research Review, 27*, 71-89. https://doi.org/10.1016/j.edurev.2019.02.001

Wang, Y., Tian, L., & Huebner, E. S. (2019). Basic psychological needs satisfaction at school, behavioral school engagement, and academic achievement: Longitudinal reciprocal relations among elementary school students. *Contemporary Educational Psychology, 56*, 130-139. https://doi.org/10.1016/j.cedpsych.2019.01.003

Warsah, I., Morganna, R., Uyun, M., Afandi, M., & Hamengkubuwono, H. (2021). The impact of collaborative learning on learners' critical thinking skills. *International Journal of Instruction, 14*(2), 443-460. https://doi.org/10.29333/iji.2021.14225a

Wei, B., Avraamidou, L., & Chen, N. (2021). How a beginning science teacher deals with practical work: An explorative study through the lens of identity. *Research in Science Education, 51*, 1-19. https://doi.org/10.1007/s11165-019-9826-z

Wei, B., Chen, S., & Chen, B. (2019). An investigation of sources of science teachers' practical knowledge of teaching with practical work. *International Journal of Science and Mathematics Education, 17*, 723-738. https://doi.org/10.1007/s10763-018-9886-y

Winkelmes, M.-A., Boye, A., & Tapp, S. (2023). *Transparent design in higher education teaching and leadership: A guide to implementing the transparency framework institution-wide to improve learning and retention*. Taylor & Francis. https://doi.org/10.4324/9781003448396-4

Xu, Z., & Shi, Y. (2018). Application of constructivist theory in flipped classroom-take college English teaching as a case study. *Theory and Practice in Language Studies, 8*(7), 880-887. https://doi.org/10.17507/tpls.0807.21

Yannier, N., Hudson, S. E., & Koedinger, K. R. (2020). Active learning is about more than hands-on: A mixed-reality AI system to support STEM education. *International Journal of Artificial Intelligence in Education, 30*(1), 74-96. https://doi.org/10.1007/s40593-020-00194-3

You, H. S., Chacko, S. M., & Kapila, V. (2021). Examining the effectiveness of a professional development program: Integration of educational robotics into science and mathematics curricula. *Journal of Science Education and Technology, 30*, 567-581. https://doi.org/10.1007/s10956-021-09903-6

Yurtseven Avci, Z., O'Dwyer, L. M., & Lawson, J. (2020). Designing effective professional development for technology integration in schools. *Journal of Computer Assisted Learning, 36*(2), 160-177. https://doi.org/10.1111/jcal.12394

Zhang, L., & Cobern, W. W. (2021). Confusions on "guidance" in inquiry-based science teaching: A response to Aditomo and Klieme (2020). *Canadian Journal of Science, Mathematics and Technology Education, 21*, 207-212. https://doi.org/10.1007/s42330-020-00116-4