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Secondary School Teachers' Conceptions of Teaching Science Practical Work through Inquiry-Based Instruction

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Abstract

Contemporary science teaching pedagogy in Namibia places a strong emphasis on fostering inquiry-based instruction and practical work in secondary school science education. In recent years, there has been a growing recognition of the need to move beyond traditional, rote-based methods towards more learner-centred approaches that encourage active inquiry and critical thinking. Teachers are encouraged to design lessons that promote inquiry, where learners actively investigate scientific phenomena, ask questions, and develop solutions through hands-on experimentation. Science practical work, which involves conducting experiments and investigations, is considered a cornerstone of this approach as it provides learners with opportunities to apply theoretical knowledge, develop laboratory skills, and gain a profounder understanding of scientific concepts. This sequential explanatory mixed methods study explored Namibian secondary school teachers' conceptions of teaching science practical work through inquiry-based instruction to provide a comprehensive understanding of teachers' perspectives and practices. Findings from this study revealed that many teachers held traditional views of science practical work, emphasizing cookbook-style experiments and memorisation. These teachers often faced challenges in implementing inquiry-based instruction due to a lack of training and resources to facilitate science practical work. However, a subset of teachers who embraced inquiry-based methods reported increased learner engagement, critical thinking, and in-depth understanding of scientific concepts. Additionally, the findings underscored the importance of aligning teacher conceptions with contemporary pedagogical approaches for effective secondary science education in Namibia. The study thus, highlighted the need for professional development and support to help more teachers transition to inquiry-based instruction and improve science education in Namibian secondary schools.

Introduction

Every country, including Namibia, recognises the critical necessity of science education in the twenty-first century and the accessibility of scientific knowledge and scientific studies has become easier. The inclusion of science learners in practical work and hands-on learning experiences is one of the most contemporary issues in science education in Namibia and across the globe (Sshana & Abulibdeh, 2020; Shivolo, 2018; Wei, Chen, & Chen, 2019; Lee & Sulaiman, 2018; Wei & Li, 2017). Muyoyeta (2018) is in agreement of the idea that science education is essential for a prosperous living in any community and that it is fundamental to providing the resources needed for a nation's socioeconomic, scientific, and technological growth. In a bid to develop a more comprehensive understanding of the natural world, learners engage in a variety of classroom activities known as 'practical work', which involve interacting with equipment and materials as well as any other type of secondary data and apprehending their findings (Wei, Chen & Chen, 2019; Hofstein, Kipnis & Abraham, 2013; Wei & Li, 2017; Abrahams & Reiss, 2012).

Practical work is regarded as a constructivist-based learning strategy where learners are encouraged to engage with real-world phenomena in order to evaluate their personal viewpoints and deepen their knowledge of what they are learning (Lee & Sulaiman, 2018). The researchers are of the idea that involving learners in hands-on activities is related to supporting teachers in reaching particular milestones in curriculum learning objectives in Namibian science classes, in particular. In contrast to learners taught science through traditional pedagogical methods emphasizing theoretical learning, those who actively engage in experiential, hands-on approaches to teaching and learning have demonstrated advanced academic performance (Lee & Sulaiman, 2018). Additionally, Lee and Sulaiman (2018) discovered that if teachers effectively organise and carry out practical work in the classroom, the learning process in which learners acquire science information is improved.

According to Jokiranta (2014), practical work can help learners conceptualize knowledge from science and also inspire them to learn science. Practical work encourages experiential learning, enables learners to discover realities not covered in textbooks, and allows them to apply concepts based on first-hand knowledge (Twahirwa & Twizeyimana, 2020).

The term inquiry has historically been described by Linn, Davis and Bell (2004) as a deliberate process of problem-solving, problem-diagnosing, evaluating experiments and identifying alternatives, planning investigations, researching conjectures, searching for information, building models, and engaging in peer debates while using evidence and representations to develop cogent arguments. In pursuit of the objective of this study, scholars within the academic community have characterised teachers' conceptions as encompassing a collection of factors, perspectives, ideas, and beliefs that pertain to teachers' perceptions of the teaching and learning processes. These conceptions have been posited to impede teachers' ability to implement inquiry-based instruction and practical activities within their classrooms (Caravias, 2018; Taylor & Booth, 2015; Bueno, 2013; Yung, Zhu, Wong, Cheng & Lo, 2013).

Subsequently, this study is centred on the objectives of comprehending, acknowledging, and documenting the conceptions held by science teachers in Namibia pertaining to the delivery of science practical work through the utilisation of inquiry-based instructional pedagogy, with the overarching goal of bringing about change and improvement in the teaching of science at secondary school level. In this sequential explanatory mixed methods study, the researchers attempted to establish the Namibian secondary school teachers' conceptions of teaching science (Physical Science, grades 8 and 9; Physics and Chemistry, grades 10 and 11) through practical work and Inquiry-Based Instruction (IBI). Thus, this study was guided by these two research questions:

1. What are the science teachers' conceptions of inquiry-based instruction?
2. What factors are informing science teachers' usage and enactment of inquiry-based instruction in their science practical work?

Literature Review

Science Teachers Conceptions

As clarified by Matos and Jardimino (2016), the term 'conception' pertains to an individual's manner of perceiving, assessing, and responding to a specific natural phenomenon, ultimately culminating in the generation of conceptualisations and ideas. According to Matos and Jardimino (2016), the phrase 'conception' encapsulates the cognitive representation of one's thoughts about a given phenomenon, thereby shaping the development of personal perspectives about the phenomena being investigated. Taylor and Booth (2015) in their study conducted in South Africa made the seminal discovery that the term 'conception' comprehensively encapsulates teachers' beliefs, perspectives, actions, and constructs pertaining to the pedagogy of science. The underpinning principles of the science subject matter to be imparted, the roles assumed by the learners, and the instructional responsibilities of the teacher, have all emerged as significant determinants influencing the perspectives held by Physical Sciences teachers in South Africa. Mokiwa and Nkopodi (2014) have concurred with these categorisations by asserting that teachers' conceptions of science pedagogy are inherently shaped by multifarious factors including their cultural milieu, educational background, technical proficiency, and opportunities for professional development.

As previously mentioned, teachers' beliefs about science education are believed to shape their pedagogical practices. Science Teaching Orientations (STOs), integral components of science teachers' Pedagogical Content Knowledge (PCK), play a pivotal role in reinforcing these beliefs. Several studies indicate that science teachers' professional knowledge (TPK) is influenced by STOs (Baptista & Molina-Andrade, 2021; Bueno, 2013; Demirdöğen & Uzuntiryaki-Kondakçı, 2016; Maseko & Khoza, 2021; Taylor & Booth, 2015). Consequently, the following sections delves into the impact of science teachers' conceptions of the nature of science as well as their teaching practices.

Conceptions in Teaching Science (CTS)

CTS encompass teachers' beliefs, attitudes, and perspectives regarding science instructional approaches. This has been emphasised in a preceding section. In a study by Mohammed and Amponsah (2021), it is proposed that teachers should cultivate well-informed conceptions on structuring information and creating authentic

educational experiences. These conceptions are conveyed to learners through representations of scientific practices that mirror the activities of real scientists, with the aim of planning and implementing inquiry-based science instruction. Additionally, to facilitate inquiry-based learning, teachers must acquire a sound understanding of how science is learned children. Teachers' proficiency in the use of inquiry-based instruction in their classrooms comprehend the roles of both teachers and learners in the inquiry process (Ireland et al., 2012; Lee & Marilyn Shea, 2016; Mohammed & Amponsah, 2021), in which they are well-versed in enhancing, guiding, coaching, mentoring, motivating, and directing learners' inquiry (Ireland et al., 2012; Mohammed & Amponsah, 2021).

Teachers with traditional or limited inquiry conceptions perceive science teaching and learning as a process of knowledge transmission and reception. They place greater emphasis on the mastery of abstract, uncontextualised knowledge, and the memorisation and recall of content, as opposed to the aforementioned perspective (Mokiwa & Nkopodi, 2014). Instead of fostering meaningful and conceptual learning, their objectives for hands-on activities are to stimulate learners' interest and engagement in science activities (Lee & Marilyn Shea, 2016; Mohammed & Amponsah, 2021).

Pedagogical Content Knowledge (PCK)

PCK holds significant importance, particularly within the modern science classroom. It encompasses both a teacher's proficiency in the subject matter and their expertise in the pedagogical methods required for the effective delivery of scientific content. The concept of PCK was introduced by Shulman in the late 1980s and has since been recognised as a vital component of a teacher's knowledge base. Shulman (1987), therefore defined PCK as "the blending of content and pedagogy into an understanding of how particular topics, problems or issues are organised, represented and adapted to the diverse interests and abilities of learners, and presented for instruction" (p. 8). Shulman (1987), further identified six fundamental types of knowledge that constitute a teacher's knowledge base, which includes: content knowledge, pedagogical knowledge, curriculum knowledge, knowledge of learners, knowledge of contexts, and knowledge of educational goals and values (Chan & Hume, 2019).

PCK has evolved into a comprehensive understanding of the relationship between content and pedagogy (Keller et al., 2017; Nilsson & Loughran, 2012). The importance of PCK in this study lies in its role in influencing a teacher's grasp of both science content and pedagogy for science education, subsequently impacting their teaching approaches and strategies aimed at enhancing learners' achievement in science. Given this study's objective of exploring teachers' conceptions concerning the implementation of science practical work using inquiry-based instruction, it is posited that PCK empowers teachers to formulate effective pedagogical approaches for delivering subject-specific content.

Science Teaching Orientations (STOs)

Within the domain of science education, STOs have been the subject of inquiry, characterised as instructional paradigms and conceptions employed by teachers in their pedagogical practices (Tylor & Booth, 2015). STOs encompass broader pedagogical beliefs and concepts within PCK and are often used interchangeably with terms like 'beliefs' and 'conceptions' related to teaching (Tylor & Booth, 2015). It is worth noting that teachers' conceptions tend to be context-bound, while teachers' beliefs are perceived as inherent attributes of a teacher (Taylor & Booth, 2015). However, Bueno (2013) discerns between perceptions, which are rooted in sensory experiences, and conceptions, which involve cognitive abstraction.

The theoretical foundations of STOs can be traced back to the model proposed by Magnusson, Krajcik, and Borko (1999), which outlines relationships among different domains of teachers' knowledge. STOs are characterised as teachers' knowledge and beliefs concerning the objectives and aims of science teaching at specific grade levels (Magnusson et al., 1999). Within the contemporary PCK model, STOs are recognised as pivotal elements that facilitate the transmission of subject-specific professional knowledge through the teacher's unique lens, combined with their beliefs, prior knowledge, and contextual factors (Demirdögen & Uzuntiryaki-Kondakçı, 2016).

Cobern et al. (2014) introduced a conceptual framework that places science teaching orientations within a broader spectrum of science teaching expertise. This spectrum relates STOs to knowledge areas such as content, practices, scientific inquiry, science pedagogy, and inquiry pedagogy. Within this framework, it is noted that

when delivering science instruction aimed at conveying scientific content, teachers are required to make epistemic decisions, either consciously or unconsciously. The science teaching epistemic mode, as illustrated in Figure 1, is further categorised into four instructional categories: didactic direct, active direct, guided inquiry, and open inquiry. Importantly, these categories should not be perceived as rigid compartments but as a practical way to describe the educational approaches used by science teachers (Cobern et al., 2014).

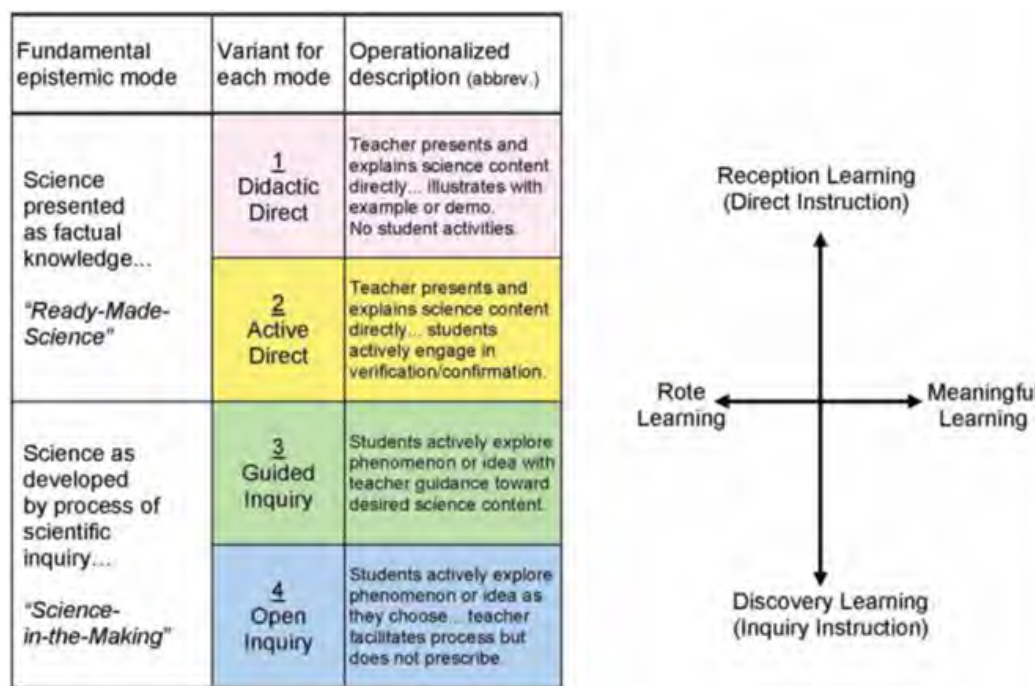


Figure 1. Pedagogical orientations of science teachers (Source: Cobern et al., 2014)

Science Practical Work in Teaching and Learning

In many countries of the world, science education places significant emphasis on practical work, as indicated by several researchers (Sshana & Abulibdeh, 2020; Wei, Chen & Chen, 2019; Lee & Sulaiman, 2018; Wei & Li, 2017; Nivalainen, Asikainen, Sormunen & Hirvonen, 2010). Practical work encompasses activities that necessitate learners to interact with real-world objects and materials, either individually or in collaboration, (Sshana & Abulibdeh, 2020); Lee & Sulaiman, 2018; Hofstein et al., 2013). Within the advocacy of the National Research Council (NRC) (2012), practical work in science education is defined as activities that may expose learners to data about the natural world, which may not necessarily pertain directly to their immediate surroundings. In North America, practical work, often referred to as ‘laboratory work’ is characterised by a wide range of hands-on activities employed by teachers in primary and secondary school science classrooms (Hofstein et al., 2013; Wellington & Ireson, 2012).

Phrases such as ‘laboratory work’ and ‘practical work’ are often used interchangeably; however, practical work encompass experiments conducted in diverse settings, including outdoor environments, classrooms, and laboratories, while laboratory work specifically refers to experiments conducted within a laboratory (Motlhabane, 2013; Wei, Chen & Chen, 2019; Wei & Li, 2017). The term ‘laboratory’ for instance is used by learners to denote a room where they can test their unique ideas and interpretations, exploring the world around them. On the contrary the term ‘practical work’ can be used by learners to describe a context in which science learners engage in hands-on activities, such as observations and experiments, not solely for verification but also for discovery and knowledge acquisition. Laboratories stand out for their capacity to encourage inquiry and questioning, showcasing objects, ideas, processes, and experiments.

To this end, for the purposes of this study, practical work, as defined by the researchers, involves activities that engage learners in active learning aimed at fostering their curiosity and expanding their knowledge of scientific phenomena under investigation. The subsequent sections will explore the expectations of the Namibian science curriculum regarding practical work, the various types of practical work in the science classroom, the advantages of incorporating practical work in science education, and the challenges associated with implementing practical activities in science classrooms.

Expectations of the Science Practical Work in the Namibian Curriculum Documents

In the context of science education in Namibia, a learner-centred approach is advocated, as explicitly articulated in the Namibian education curriculum documents. This instructional viewpoint is reinforced by multiple official curricular policy documents, which underscore the significance of learners engaging in hands-on practical activities within science classes. Notable references to this pedagogical emphasis can be found in several documents, including the Physical Science Syllabus for Grades 8 and 9 (2015), the National Curriculum for Basic Education (MoEAC, [NCBE], 2018, the Chemistry and Physics Syllabi for Advanced Subsidiary Level Grade 12 (2020), as well as the Chemistry and Physics Syllabi for Ordinary Level (2018) Grades 10-11. These documents were reviewed to determine their level of inclusion of science practical work and the advocacy of inquiry-based instruction in the implementation of the science curriculum.

The Expectations from the Science Syllabuses

The Junior Secondary phase in Namibia serves as a transitional period bridging the primary and secondary education levels, with the primary objective of preparing learners for more advanced science courses in their subsequent academic pursuits and real-world applications. Within this phase, the Physical Science syllabus outlines the expectations for both learners and teachers in the context of science teaching and learning. According to the syllabus, active engagement and participation of learners in the learning process are emphasised as essential for effective learning outcomes (Physical Science Syllabus Grades 8 & 9, 2015). Furthermore, the syllabus highlights the importance of teachers' ability to discriminate the unique learning requirements of learners and tailor their pedagogical approaches accordingly throughout their lessons. In the context of the senior secondary phase, the syllabuses for subjects like Chemistry and Physics underscore the experimental nature of these disciplines. As a result, there is a need for an assessment component that evaluates learners' scientific knowledge and understanding in relation to practical work and experimental techniques (Chemistry Syllabus Advanced Subsidiary Level Grade 12, 2020; Physics Syllabus Advanced Subsidiary Level Grade 12, 2020; Chemistry Syllabus Ordinary Level Grade 10-11, 2018; Physics Syllabus Ordinary Level Grade 10-11, 2018). These syllabuses delineate three distinct assessment objectives: A, B, and C.

Assessment objective A primarily centres on assessing knowledge and understanding, while assessment objective B places emphasis on the application of information and problem-solving skills. The central point of this study pertains to assessment objective C, which is dedicated to practical (experimental and investigative) skills and abilities, with a specific focus on science practical work. This focus on assessment objective C is of particular significance in the context of evaluating learners' proficiency in science practical work. To this end, teachers are expected to ensure that learners engage in hands-on experimental practice throughout their lessons and course of study to fulfil the requirements of the assessment objective. According to the Physics Syllabus for Advanced Subsidiary Level Grade 12 (2020), learners should "spend at least 20% of their time doing practical work individually, or in small groups, and this 20% does not include the time spent observing teacher demonstrations of experiments" (p. 31). This implies a strong emphasis on active learner participation in experimental techniques (which is the focus of this study) rather than passive observation and learning science through theoretical methodological approaches.

Classification of Science Practical Work in the Science Classrooms

Numerous scholars in the field of science education have emphasised the significance of incorporating practical work within the science classroom, underscoring its pivotal role. Wei and Liu (2018) asserted that practical experimentation is closely intertwined with empowering learners to independently interpret scientific phenomena. Furthermore, Teo, Tan, Yan, Teo, and Yeo (2014) posited that engaging in hands-on practical activities can enhance and "facilitate the understanding of scientific concepts and the nature of science (NOS), provide opportunities to learn inquiry skills and problem solving, cultivate scientific habits of mind, and help students to develop a positive attitude towards science and the learning of science" (p. 551).

Various science scholars have explored the diverse aspects of science practical work, which encompasses activities such as experiments, investigations, discovery tasks, discovery approaches to teaching, and the process approach (Abrahams & Reiss, 2012; Jokiranta, 2014; Kidman, 2012; Motlhabane, 2013; Sedumedi, 2017; Twahirwa & Twizeyimana, 2020). Kidman (2012) classified seven distinct types and/or categories of science practical work employed by educators within science classrooms. These categories include demonstrations, laboratory experiments or closed inquiry, directed activity, undirected activity, skill development, guided

inquiry, and open inquiry. Kidman's research, which was conducted in Australia, suggested that each of these categories of science practical work fulfils a unique role in enhancing the learning experience for learners.

Benefits of Teaching Science through Practical Work

The primary purpose of incorporating practical work in science education is to equip young individuals with a robust conceptual understanding of scientific principles, enabling them to engage confidently and effectively in the contemporary world of the STEM era. In essence, this pedagogical approach emphasises the cultivation of scientific literacy among learners (Jagodziński & Wolski, 2015; Motlhabane, 2013; Twahirwa & Twizeyimana, 2020). Additionally, an essential objective of science education through practical work is to provide learners with concrete scientific foundations that will prepare them for future employment in science related fields (Motlhabane, 2013).

Practical work is proposed as a means to enhancing learners' appreciation of scientific knowledge and to cultivate their problem-solving skills, offering them insight into the scientific process through hands-on experimentation (Sshana & Abulibdeh, 2020). Accordingly, researchers support that learners should emulate scientific methodologies when tackling scientific problems (Sshana & Abulibdeh, 2020; Sofoklis et al., 2017). The inclusion of science practical work in the learning process is justified by the objective of granting learners the autonomy to conduct their own scientific experiments and investigations, thereby facilitating the development of their scientific knowledge. In line with this, learners are perceived as active contributors to the construction of their scientific knowledge, (Bradley, 2021; Sshana & Abulibdeh, 2020; Twahirwa & Twizeyimana, 2020). In particular, Bradley's (2021) study highlights the various goals associated with teaching science in educational settings as outlined by a number of science experts.

In accordance with this, the Physics and Chemistry syllabi for the ordinary level have been designed to prepare learners for a special assessment form, denoted as paper 3, which evaluates their aptitude in experimental techniques, aligned with assessment objective C outlined in these syllabi. Accordingly, the official curriculum document underlines "the best way to prepare candidates for these papers is to integrate practical work fully into the course so that it becomes a normal part of your teaching" (Physics Syllabus Ordinary Level Grade 10 – 11, 2018, p. 45).

Factors Impeding the Implementation of Inquiry

Despite the acknowledged advantages of inquiry-based instruction in science education, the literature highlights significant difficulties hindering the effective implementation of such teaching methods. These barriers have been identified in previous studies by many science researchers (Capps et al., 2012; Baroudi & Rodjan Helder, 2021; Letina, 2021; Pesqueira, 2021). The impediments can be categorised as enduring and practical challenges that have deterred science teachers from adopting inquiry-based pedagogies over the years. They include teachers' epistemological beliefs about teaching and learning science through inquiry, their content and pedagogical content knowledge related to inquiry (van Driel et al., 2014), the availability of suitable curriculum materials (Baroudi & Rodjan Helder, 2021; Letina, 2021; Pesqueira, 2021), learners' attitudes or resistance to inquiry-based learning the cost of materials that may influence teachers' teaching decisions, teachers' challenges in redirecting questions to learners' difficulties in teaching mandated concepts through inquiry, and classroom management issues (Crawford, 2014). These challenges have been identified as inhibiting teachers' ability to effectively implement inquiry-based instruction in science classrooms worldwide.

In his study on examining the impact of intrinsic and extrinsic factors on inquiry-based instruction in South Africa, Ramnarain (2016) found that science teachers often experience intrinsic uncertainty when it comes to implementing inquiry-based teaching in their classrooms. This uncertainty stems from their perception of shortages in various aspects of their professional knowledge, including content knowledge, pedagogical knowledge, pedagogical content knowledge, understanding of their learners, awareness of the educational context, familiarity with the curriculum, and the overall educational knowledge.

To this end, a comprehensive examination of the literature also reveals several key factors that influence or impede the adoption of inquiry-based science instruction in science classrooms globally (Baroudi & Rodjan Helder, 2021; Letina, 2021; Pesqueira, 2021). Ultimately, while inquiry-based instruction has been in practice in many countries globally, it is imperative to promote a shift in the perspectives of both teachers and learners. This approach is recognized as a catalyst for 21st learners to embrace emerging scientific knowledge and skill sets.

Theoretical Framework

This study is guided by two theoretical frameworks, namely the constructivist theory of learning (Dewey, 1929) and the social cognitive theory (Holt & Brown, 1931), which serve as foundational pillars for the development of the research's theoretical lenses. These theories have played a crucial role in shaping the overarching theoretical framework within which the research objectives are situated.

The theoretical framework serves as the blueprint upon which the study's theoretical assumptions and foundations are constructed. The subsequent section of this study is dedicated to the presentation, elaboration, description, and justification of the contextualisation of the theoretical and conceptual frameworks that underpin this study. It is therefore imperative that the significance of these theories in the context of the current study, with a specific focus on understanding teachers' conceptions of teaching science practical work through inquiry-based instruction in Namibian secondary schools.

Constructivist Theory of Learning

This study was grounded in the constructivist theory of learning, which asserts that knowledge is derived from experiential learning, with active learner engagement at its core. This theoretical foundation prompted a comprehensive inquiry into teachers' conceptions and experiences in teaching, particularly in the context of inquiry-based science practical work. Recent educational research trends, such as the Conceptual Learning Theory (CLT), served as motivation. The study's primary goal was to determine if a significant connection exists between teachers' beliefs of enacting inquiry-based methods for teaching science practical work and their actual classroom practices contributing valuable insights to scholarly literature.

The Social Cognitive Theory

This theory has been chosen to underpin this study as it holds the view that learners pick up knowledge by watching others. The environment, behaviour, and cognition are the main determinants of development. These three variables interact with one another in a process known as triadic reciprocal determinism which posit the fact that learners are not static or separate entities (Bandura, 2014; Bandura, 1989). The theory is contextualised in this study as it posits the fact that, learners can learn directly from others, in the context of social interactions, experiences, and outside media influences. Hence, imitation of others' conduct is essential for human survival, which is why teachers are contextualised as exemplary role models in this study, people do not learn new behaviours just by attempting them, and either succeeding or failing at them.

Method

This study employed a sequential explanatory mixed methods approach, as advocated by many scholars (Hitchcock & Onwuegbuzie, 2020; Tashakkori & Teddlie, 2021). It begins with the collection and analysis of quantitative data, followed by the collection and analysis of qualitative data. A mixed methods approach is characterised by its integration of techniques and methods from both quantitative, associated with a positivist paradigm, and qualitative, associated with constructivist or interpretivist paradigms, within a single study (Hitchcock & Onwuegbuzie, 2020; Onwuegbuzie & Hitchcock, 2022). This approach allowed researchers to gather and analyse both types of data within a single study, facilitating a comprehensive exploration of a research problem (Onwuegbuzie & Hitchcock, 2022; Tashakkori & Teddlie, 2021).

Context and Participants in the Study

The current study encompassed teachers from all the 14 educational regions within Namibia. A majority, exceeding 50%, of the teachers who partook in this research were located in schools situated in rural areas. The participants were of a mature age, with nearly 50% falling within the age range of 31 to 40 years. Furthermore, all participants possessed a minimum of five years of pedagogical experience, specialising in either the teaching of Physical Science for grades 8 and 9 or Physics and Chemistry for grades 10 to 11.

Moreover, approximately 85% of these teachers held permanent positions and concurrently fulfilled roles as classroom and/or subject teachers, while the remaining 15% assumed positions as Heads of Departments

(HoDs) or school principals. This distinction implies that teachers who participated in this study focused their efforts towards teaching tasks other than to administrative responsibilities, rendering them well-suited for the current study. Despite the suitability of the selected teachers for this study, it is noteworthy that only around 30% of the schools where they were stationed were adequately equipped with the necessary resources to facilitate practical science work. The remainder of the schools fell into various categories, characterised as ‘well-resourced’, ‘poorly resourced’ or having ‘no resources’ available for this purpose.

Data Collection Procedures

In this present study, the researchers employed several methods of data collection to explore the conceptions of teaching science practical work through inquiry-based instruction among secondary school teachers in Namibia. The first phase of data collection which was the quantitative stage of the study which involved 133 science teachers in Namibia who responded to a questionnaire survey. The selection of a questionnaire was considered appropriate due to the researchers’ intention to obtain a hefty amount of data from a larger participant pool, which was aimed at providing insights into the study’s research questions one to two (Hitchcock & Onwuegbuzie, 2020; Onwuegbuzie & Hitchcock, 2022; Tashakkori & Teddlie, 2021).

The qualitative phase involved the selection of 10 teachers from a larger group of 133 teachers who had previously participated in an online questionnaire survey for classroom observations and interviews. These teachers were selected based on their experiences in teaching science, their mature age and their availability. The combination of classroom observations and teacher interviews was employed to help the authors understand how teachers’ perceptions of inquiry-based instruction influenced their approach to practical work.

The observations focused on various aspects, including how teachers facilitated practical activities and implemented inquiry-based instruction, as well as the roles of both teachers and learners during these activities. The level of learner autonomy during these practical sessions was also assessed. Each teacher was observed in their natural classroom environment at their respective schools once. Following the classroom observations, the same 10 teachers were interviewed to gain further insights into their teaching practices. These interviews were also conducted once with each teacher and were aimed at exploring their experiences and expertise in teaching science practical work. The interviews were audio recorded and subsequently transcribed.

Data Analysis

The data analysis process varied depending on the type of data collected. For the quantitative data obtained through the questionnaire survey, statistical analysis was conducted using IBM SPSS-PASW version 27 (IBM Corp., 2020). This allowed for the generation of quantitative insights, including descriptive statistics and inferential analyses, to determine patterns and relationships among the participants’ responses. In the case of the qualitative data collected from classroom observations and semi-structured interviews, thematic analysis was employed (Dawadi, 2020; Saldaña, 2015). Researchers systematically examined the data, identifying recurring themes, patterns, and categories that emerged from the teachers’ responses and observed practices. This approach helped in uncovering the subtle and context-specific conceptions of teaching science practical work through inquiry-based instruction.

Thematic analysis represents a qualitative data analysis approach that allows researchers to systematically arrange and assess extensive and intricate data sets, as described by Dawadi in 2020. Furthermore, Dawadi (2020) highlights the central aspect of thematic analysis, involving the meticulous review and re-examination of transcribed data to discern prevalent themes. Similarly, Clarke, Braun, and Hayfield (2015) expound upon thematic analysis, characterising it as a method for recognising, decoding, and clarifying patterns of significance, commonly referred to as ‘themes.’ Subsequently, Sundler, Lindberg, Nilsson, and Palmér (2019) have provided a framework that encapsulates the essence of thematic analysis, as depicted in Figure 2., which was followed in the present study to guide the research process.

As it can be seen in Figure 2., the authors engaged in a systematic process to immerse themselves in the data, involving a thorough review of transcribed materials, the exploration of underlying meanings, and the subsequent organisation of data into coherent patterns. In the context of this research, the qualitative data analysis approach employed a deductive coding technique to derive themes, categories, and assertions from the data.

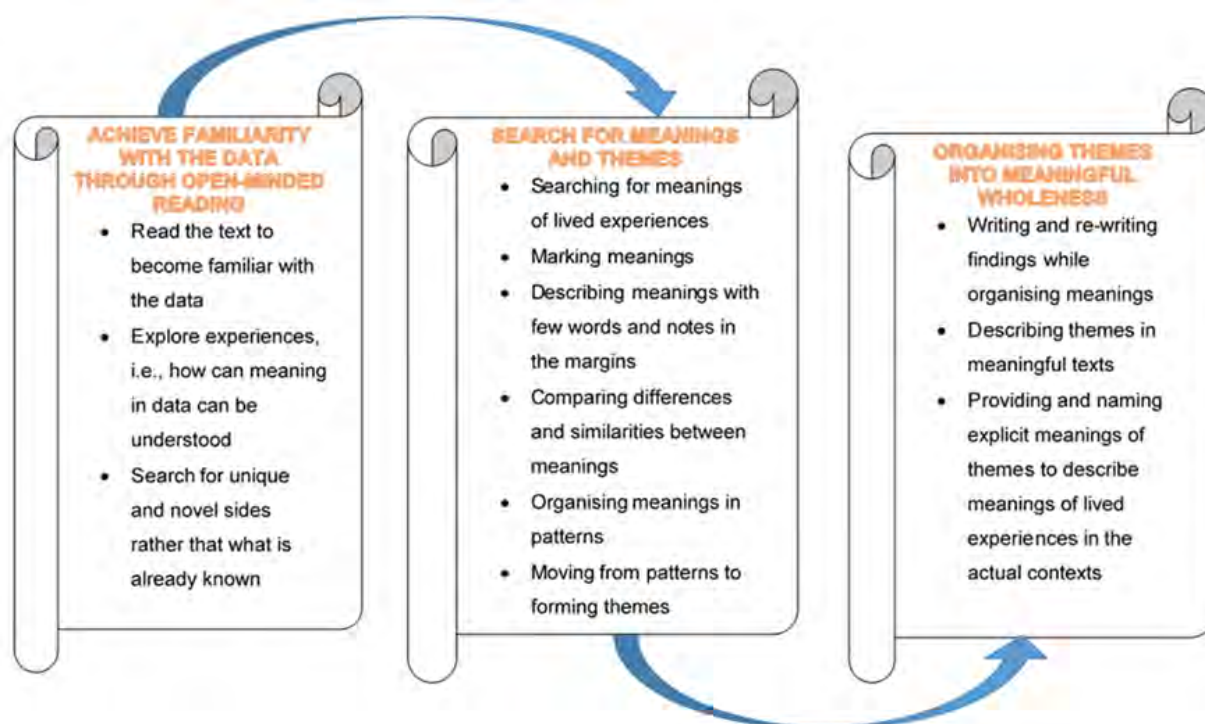


Figure 2. The summary of thematic analysis (Source: Adapted from Clarke, Braun, & Hayfield, 2015)

Results

This section presents the findings of the study, encompassing a comprehensive analysis of each research question. To enhance clarity and comprehension, relevant extracts are incorporated, and the data is systematically arranged within designated subsections. This structure is designed to facilitate the readers' grasp of the discourse and the explanation of the research findings.

Science Teachers' Conceptions of Inquiry-Based Instruction and Science Practical Work

The questionnaire survey data, classroom observations, and teachers' interviews showed that teachers have strong conceptions about the enactment of inquiry-based instructions in their classrooms.

Data from Questionnaire Survey

Several criteria were employed to ascertain the views of teachers regarding inquiry-based instructional methods, as illustrated in Table 1. The participants' conceptualisations played a pivotal role in gauging their comprehension of inquiry-based instruction within the scope of the current study. Teachers were tasked with providing responses on a numerical scale ranging from 1 to 5, denoting degrees of agreement such that: 1 = Strongly disagree, 2 = Disagree, 3 = Neutral/undecided, 4 = Agree, and 5 = Strongly agree.

The results, presented in Table 1, revealed an overall mean score of 4.36, accompanied by a reasonably consistent standard deviation of 0.64, concerning the objectives relating to teachers' perspectives on inquiry-based instruction. This outcome suggests that a substantial proportion of teachers hold multifaceted perspectives on inquiry-based instruction, considering them integral to the implementation of science practical work in Namibian science classrooms. Subsequently, based on these findings, it is agreeably emphasised that a majority of teachers espouse robust views regarding the significance of inquiry-based instruction in the teaching pedagogy of science.

With regards to the enactment of science practical work, teachers appear to have informed views, attitudes, and beliefs (conceptions) in terms of their practices about inquiry-based instructions. Table 2, depicts the data

analysis of data regarding teachers' practices, views, attitudes, and beliefs of using inquiry-based instructions in the teaching of science practical work.

Table 1. Science teachers' views of inquiry-based instruction

To determine the science Teachers' views of inquiry-based instructions	n	M	SD
Inquiry-based instruction is a learner-centred approach that invites learners to explore content by posing, investigating, and answering questions.	133	4.44	0.62
Through inquiry, learners are usually actively engaged in discovering information to support their investigations.	133	4.47	0.54
Inquiry-based instruction is a powerful way of learning science, regardless of a learner's language background	133	4.43	0.65
Inquiry-based instruction puts learners' questions at the centre of the science curriculum.	133	4.34	0.64
Inquiry-based instruction places as much emphasis on research skills as it does on knowledge and understanding of the science content.	133	4.32	0.67
Within inquiry-based instruction, teachers usually commit to providing rich experiences that provoke learners' thinking and curiosity to conduct their own experiments.	133	4.46	0.65
Using an inquiry-based approach allows learners to draw connections between scientific content and their own lives.	133	4.45	0.62
In an inquiry-based classroom, learners are given opportunities to take ownership of their own learning.	133	4.47	0.58
Inquiry-based teaching inspires learners to learn more and to learn more thoroughly.	133	4.32	0.70
Inquiry-based teaching methods can benefit both culturally and linguistically diverse learners and learners with special needs and learning difficulties.	133	4.28	0.72
An inquiry-based approach to teaching can increase learners' achievement and narrow the gap between high- and low-achieving learners.	133	4.26	0.68
When used in place of a traditional textbook approach, an inquiry-based approach can yield significantly higher achievement for learners with learning difficulties.	133	4.28	0.54
Learners develop a sense of belonging through inquiry-based instructions as they allow them to participate in activities such as group projects, science projects, and unique exercises designed for specific groups of learners.	133	4.46	0.58
Inquiry-based instruction helps learners focus on open questions or problems to use evidence-based reasoning, creative thinking, and problem-solving to form a conclusion they can defend.	133	4.41	0.49
Inquiry-based learning enables teachers to help learners get from the curiosity stage into critical thinking and deeper levels of understanding of science concepts.	133	4.44	0.54
In an inquiry-based classroom, teachers are usually viewed as not doing anything, as learners usually formulate questions and seek out answers.	133	3.93	1.08
TOTAL	133	4.36	0.64

Based on this empirical data from the participants, the results gave an impression that inquiry-based learning adds value to the experimental learning that classify learners not as a bank of information, but rather as practical players in the inquiry-based instruction. Furthermore, these results are notably indicative that teachers' practices, views, attitudes and beliefs of using inquiry-based instructions in the teaching of science practical

work are positive as a total average strong mean score of 4.36, and a notably constant standard deviation of 0.65 were scored.

Table 2. Teachers' classroom practices in enacting inquiry-based instruction in science practical work

	n	M	SD
Inquiry-based science instructions challenges learners' thinking by engaging them in scientifically oriented questions in which they learn to prioritize evidence, evaluate explanations, and in light of alternative explanations, and communicate and justify their decisions.	133	4.37	0.58
Using inquiry-based instructions enables learners to develop the dispositions needed to promote and justify their decisions.	133	4.33	0.57
Inquiry-based learning improves learners' understanding of scientific concepts and increases their interest in the subject.	133	4.40	0.62
When learners are provided with autonomy of scientific inquiry, it enables them to conduct their own practical work.	133	4.32	0.63
By allowing learners to explore topics on their own and create their own learning process, inquiry-based learning instils fun and engagement in the practical work of science.	133	4.38	0.66
When learners have control over their learning process, they become more engaged, which contributes to the development of a passion for exploration and learning at a higher level and the development of their own practical work.	133	4.41	0.68
Using inquiry-based instructions in science practical work helps learners improve their understanding, develop their problem-solving skills, and understand the nature of science.	133	4.35	0.68
Inquiry-based instructions encourage learners to make links between their theoretical and practical knowledge.	133	4.42	0.65
Inquiry-based instruction supports science practical work by keeping learners focused on the task while they are engaged in hands-on activities.	133	4.33	0.65
Inquiry-based instruction prepares learners' minds for science practical work by providing background information on what they are investigating.	133	4.37	0.65
As a teacher is viewed as a facilitator in an inquiry-based classroom, learners usually have full autonomy in carrying out their science practical work.	133	4.23	0.76
Inquiry-based learning as a stepping stone towards practical work provides opportunity for experimental learning, in which a learner can prove a scientific theory rather than memorizing facts.	133	4.40	0.65
TOTAL	133	4.36	0.65

Data from Classroom Observations

During the process of classroom observation, each of the 10 teacher's instructional practice was subject to analysis while enacting a practical activity or experiment. The diversity in the nature of practical activities among teachers became apparent, outlined by their preferences, encompassing both teacher-guided and learner-initiated modes (referred to as learner-led practical activities).

Table 3. Teachers' observation schedule

Teacher's Name	Subject Observed	Grade
Teacher Nangula	Physical Science	9B
Teacher Simasiku	Physical Science	8C
Teacher Nanub	Chemistry	10A
Teacher Kamina	Physics	11B
Teacher Maluleke	Physical Science	11A
Teacher Ingrid	Chemistry	11D
Teacher Beullah	Physics	9C
Teacher Fritz	Chemistry	11B
Teacher Tangeni	Physics	11A
Teacher Manyando	Physics	10B

The ensuing analysis focused on distinct behavioural indicators differentiated throughout the observational sessions, namely: the degree of learners' engagement in the assigned task, instances of off-task behaviour among learners, disruptive conduct exhibited by learners during practical tasks, and positive manifestations of behaviour, such as learners assisting peers or the teacher in handling experimental apparatus. Table 3., shows the summary of teachers where the classroom observations were conducted in terms of the subjects in which teachers were observed and the grade classes they taught. These are not the teachers' real names; hence pseudonyms were used.

According to the observation conducted in Teacher Nangula's class, it was noted that the class size exceeded the recommended teacher-learner ratio (1:35) for junior secondary education in Namibia (Ministry of Basic Education and Culture, 2001). The lesson observed primarily involved a teacher-led practical activity, wherein the teacher explained procedures and instructions before prompting learners to predict experiment outcomes. Despite the syllabus recommending learner engagement in practical activities, the teacher played a central role in facilitating the experiment, with learners assisting in handling apparatus. While the teacher remained central, the active participation of learners in the activity was evident. The findings suggest that granting teachers opportunities to authorise independent science practical work for learners could be an effective strategy to foster independent inquiry and instil confidence in carrying out practical tasks autonomously. This, in turn, may promote consistent positive behaviour in the classroom, aligning with the adoption of inquiry-based approaches to teaching science.

Teacher Nanub's classroom observation revealed a pedagogical approach wherein learners were instructed to independently formulate questions, hypotheses, and predictions related to the production and testing of carbon dioxide gas. This method aligns with the principles of inquiry-based science education, emphasising the importance of learners actively engaging in the scientific process. The observed collaborative efforts among learners in reaching a common conclusion further underscored the true sense of the implementation of the inquiry-based instructional concept during practical work. The observation emphasised the adherence to suggested practical activities in the curriculum, coupled with well-formulated lesson plans, enhances learners' enjoyment of science learning and fosters confidence in independent practical work. This proactive engagement contributes to the development of practical skills, enabling learners to address examination questions related to such skills. The positive outcomes observed were attributed to learners' active involvement, effective communication of experiment results, and successful completion of assigned assessment tasks.

In the context of the classroom observations conducted in Teacher Maluleke's class, it became evident that the size of the class poses challenges to the implementation of science practical work. The constrained space, limited apparatus, and limited lesson time impede teachers from assigning individual tasks to learners. Despite these constraints, collaborative learning styles emerge as a means for learners to develop their own approaches to practical activities. However, it is crucial to note that while learners may formulate their own methods, the teacher retains autonomy in experiment planning and instruction. The classroom observation schedule further affirms that, despite teachers providing guidance, learners often exercise autonomy in carrying out practical activities.

Teacher Beullah's classroom observation yielded that inquiry-based instruction play a pivotal role in fostering learners' curiosity. This is evident as learners, when exposed to scientific phenomena, demonstrated an increased propensity to inquire further into the reasons behind observed phenomena. An illustration of this is observed during pH tests on various food substances, wherein learners exhibit a curiosity to understand the distinct effects of different substances on indicators. The essence of inquiry-based science instruction lies in prompting learners to articulate and interpret their investigative processes and outcomes. The analysis of the observation schedule suggests that active engagement in tasks enables learners to draw meaningful conclusions, and they display an ability to categorise and group objects or substances based on observed characteristics resulting from practical activities.

In the observation of Teacher Tangeni's instructional approach, despite a class size slightly exceeding the anticipated teacher-learner ratio, learners engaged in collaborative group practical activities under the teacher's guidance. Although Teacher Tangeni maintained an authoritative role, the findings indicated a cooperative effort among the learners. On the other hand, the classroom observation of Teacher Manyando underscored teachers' efforts to promote a learner-centred approach, granting autonomy to learners in driving the learning process. Interestingly, the teacher's favourable disposition towards science practical work was found to be unrelated to class size but rather connected to the implementation of the science curriculum emphasizing hands-on activities. Despite a class size exceeding 30 learners, the observation schedule revealed the teacher's unwavering optimism and enthusiasm for prioritising practical work. The teacher facilitated independent group work, wherein learners

formulated hypotheses, conducted practical experiments, and provided justifications based on their findings. Consequently, a teacher's positive perspective on practical science is evidently intertwined with their instructional practices in the classroom.

From these classroom observations, it was evident that a significant number of teachers favoured fostering learner autonomy through hands-on practical activities. However, the findings underscored challenges in the execution of science practical work, including issues such as classroom size constraints, insufficient availability of materials for practical work in science, teachers' attitudes towards practical science instruction, and learners' conduct during practical activities. The observed behaviours of both teachers and learners can be recorded as follows:

- Teachers typically explain the procedures of practical activities or experiments before their implementation, whether conducted by the teacher or independently by learners.
- Learners formulate hypotheses or predictions regarding the outcomes of experiments.
- Learners work autonomously or collaboratively, providing mutual assistance, with minimal teacher intervention.
- Learners prefer selecting apparatuses and conducting experiments individually or in groups.
- Learners derive their own conclusions from the experiments based on personal results and findings.
- Teachers subsequently administer assessment activities related to the recently concluded experiments.

Data from Interviews

Teachers were interviewed to provide insights into their instructional approaches aligning with the advocacy of the science curriculum outlined by the NCBE and the National Subject Policy for Physical Science. This study focused on Grades 8 and 9 Physical Science and Physics or Chemistry for Grades 11 to 11 in Namibian schools. The interview data underwent thematic analysis, with themes developed following Sundler et al.'s (2019) framework. The process involved familiarisation with the data, extracting meaning, and organising information to generate themes. This approach facilitated a comprehensive understanding of science teaching practices among Namibian teachers. An essential aspect in the present implementation of science practical work in Namibian schools is the understanding of inquiry-based instruction by teachers. In soliciting their perspectives, participants were prompted to explain their understanding of this instructional approach during the interviews, yielding diverse responses from the teacher cohort. Some of the teachers have this to say regarding their understanding of science practical work using inquiry-based instruction:

When it comes to enquiry-based instruction it has to do with learners' and strategies, where learners come up with their own constructive ways of learning during the teaching process (Teacher Kamina).

The strategy that I normally employ in my class is just for the learner to carry out their own experiment so that they know exactly what they want to find out in that practical (Teacher Ingrid).

What I understand by the concept of inquiry-based instruction is the ability for learners to direct their own learning by being involved in their learning through asking questions, that direct the teaching of the content, that direct the teaching strategies of the teacher (Teacher Nanub).

I believe it's a way of involving learners in what they are learning to take over the learning into their hands and they carry out investigations and then they come to results through the guidance of the teacher (Teacher Nangula).

The way I understand the enquiry-based instruction, for me it's more like learners' circle, where you give them the autonomy, say autonomy of taking more responsibility in doing, you know the practical, like you know, through where you can at least give instructions and then they do it on their own, you know, you give them more power, instead of you as a teacher doing it for them it depends more on how they understand it (Teacher Fritz).

Based on insights gathered from interviews with teachers, it became evident that teachers recognise the pivotal role of learners assuming responsibility for their learning in science within an inquiry-based instructional framework. Teachers emphasise the shift from a traditional model where learners passively receive information from the authoritative teacher to a dynamic paradigm where learners actively engage in their learning process. The consensus among teachers is that inquiry-based instruction serves as a vehicle for fostering learner autonomy, and empowering them to take charge of their educational journey. This instructional approach, as articulated by teachers during interviews, entails learners formulating questions and independently conducting scientific inquiries. The teachers generally highlight the importance of guiding and directing the learning trajectory, refuting the notion that inquiry-based education is synonymous with unfettered learner autonomy. Instead, they advocate for a balanced approach, incorporating structured guidance to facilitate active learning, critical thinking, and overall educational autonomy.

To ascertain teachers' perspectives on the implementation of inquiry-based instruction as a pedagogical approach, the first author conducted interviews wherein participants were asked to give their opinions on the assertion that "inquiry-based instruction as a teaching strategy is currently preferred when enacting science practical work. What do you make of this statement?" The objective was to gain insights into teachers' perceptions of the extent to which the adoption of inquiry-based instruction influences their instructional methodologies. The extracts hereunder outline teachers' responses to the statement:

Inquiry-based instruction is an ideal teaching strategy when teaching science practical work because; it helps learners to develop science techniques and to master the science technics. It allows learners to develop critical thinking skills; it also allows learners to just develop the scientific phenomena as students and as science professionals in the future (Teacher Simasiku).

I believe this teaching strategy it is preferred and I think, it is preferred with a reason, reason being as we have discussed earlier, inquiry based-instructions they are much more practical right, and they allow the learner to experience the process for themselves which is much better than just hiding information, because in that way there is no much learning being done more especially with science practical one, science practical work is all about being hands-on, it's all about working with objects, it's all about conducting experiment. Inquiry based instruction allows learners or gives learners the autonomy to go out there and do things for themselves and conduct experiments for themselves and that works hand in hand with science practical work because they are the ones who supposed to do it and they are the ones who supposed to learn from it (Teacher Nangula).

Maybe is preferred because it gives good results, also learners learn a lot more on their own given instructions (Teacher Tangeni).

According to teacher responses, the implementation of inquiry-based instruction facilitates self-regulated learning in learners by stimulating their curiosity and equipping them with the necessary skills to comprehend the manipulation of objects. This pedagogical approach fosters learner autonomy in object manipulation, diminishing the reliance on teacher support. Consequently, it is posited that learners, under this framework, are capable of independently engaging in activities and achieving desired outcomes.

Factors Informing Science Teachers' Usage and Enactment of Inquiry- Based Instruction

To gain insight into teachers' classroom methodologies concerning the enactment of science practical work, an analysis of their teaching pedagogies and orientations became imperative. The effectiveness of practical work implementation in classrooms is depending upon various factors that either facilitate or hinder the process. Teachers revealed the following as factors informing their practices of engaging learner in practical work as exemplified by these teachers' extracts:

The way I was taught in school as a learner and the way I was trained as a teacher during my initial teacher training (Teacher Manyando)

My own understanding of what inquiry-based instruction is and its relevance and relatedness to practical work (Teacher Fritz)

My own attitudes, views and beliefs about the nature of science, the amount of time from the timetable for teaching science and the time to be spent by the learners on doing science practical work (Teacher Nanub)

Learners' behaviours, attitudes and views of inquiry-based instructions, my teaching workload, for example the number of periods I have in the week (Teacher Nangula)

The availability of resources and equipment to do science practical work (Teacher Beaulah)

These factors thus significantly influence the dynamics of science practical work within educational settings. An understanding of teachers' classroom practices in terms of their teaching pedagogies and orientations in the enactment of science practical work relies largely on the factors as emerging from the study which inform or impedes the successful implementation of practical work in their classes.

Discussion

In the context of teachers' conceptions on inquiry-based instruction in the implementation of science practical work, the questionnaire results indicated a strong awareness among teachers regarding the learner-centred approach and the fundamental principles of inquiry-based learning. The instructional approach of inquiry is perceived as a facilitator for learners to explore and comprehend content through the formulation, exploration, and response to questions. The study revealed that during inquiry-based learning, learners actively participate in acquiring information to bolster their investigative skills. This assertion is substantiated by the questionnaire data, reflecting a consistently high mean score of $M = 4.36$ with a standard deviation of $SD = 0.64$. Furthermore, a significant proportion of teachers acknowledged that learners typically engage actively in the acquisition of information to support their inquiries within the framework of inquiry-based instruction. These results align with the structure of Namibian science syllabi and the national subject policy, emphasising learner-centred education. This instructional approach is advocated for Namibian schools, as outlined in the Ministry of Education, Arts and Culture (MoEAC) documents such as the Chemistry Syllabus Advanced Subsidiary Level Grade 12 (2020), Physics Syllabus Advanced Subsidiary Level Grade 12 (2020), Chemistry Syllabus Ordinary Level, Grade 10 – 11 (2018), Physics Syllabus Ordinary Level, Grade 10 – 11 (2018), Physical Science Syllabus Grades 8 & 9 (2015), and the National Subject Policy Guide for Physical Science, Grades 8 - 9, Physics and Chemistry, Grades 10 - 12 (2020) (MoEAC [NCBE], 2018).

Inquiry-based instruction have been shown to be a successful way for teaching and learning science to multi-lingual learners, regardless of a learner's language background. This suggests that respondents trust inquiry-based instruction to be a successful method for teaching and learning science in Namibian classrooms, even though learners come from a variety of sociolinguistic backgrounds. These findings are in accordance with Ramnarain and Hlatswayo (2018), who in their study also revealed that inquiry-based instruction appear to motivate and support learners in the understanding of abstract science concepts. The results of the present study indicated that teachers who possess a complete understanding of inquiry-based instructional methods and their advantages in the science classroom are inclined to integrate these approaches. This integration, in turn, has the potential to enhance learners' conceptual understanding of scientific phenomena, consequently contributing to improved academic performance. Furthermore, a prevailing consensus among science teachers in Namibia suggests a shared perspective on the central positioning of learners within the science curriculum through inquiry-based education. Notably, inquiry methods underscore the development of learners' research skills, complementing the acquisition of scholarly knowledge and comprehension derived from theoretical learning in the field of science.

Based on the findings from the current study teachers' employing inquiry-based learning exhibit a commitment to facilitating meaningful learning experiences for learners, fostering curiosity, and motivating independent experimentation. With a mean score (M) of 4.36 and a consistently low standard deviation ($SD = 0.65$), learners utilising this approach can establish connections between scientific content and their personal lives. The constant mean and dependable standard deviation substantiate teachers' contentions, highlighting the efficacy of inquiry-based methods in fostering links between scientific phenomena and learners' life experiences. Corroborating these findings, scholars in the field of science education posit that teachers employing inquiry-based pedagogy contribute to the development of critical thinking, problem-solving, cooperative and collaborative skills, information analysis, and the cultivation of scientific curiosity in learners. Additionally, these teachers provide authentic learning processes mirroring real-life models (Baroudi & Rodjan, 2021; Gholam, 2019; Marks, 2013).

To this end, in the Namibian context, the implementation of inquiry-based instructional methods has demonstrated a positive correlation with enhanced learner motivation and depth of understanding. The utilisation of inquiry-based instruction is deemed crucial in the realm of science education, serving as a pedagogical approach that not only imparts information but also inspires and propels learners to delve deeper into scientific phenomena, fostering a more comprehensive comprehension thereof. This instructional strategy contributes significantly to the cultivation of an inquisitive and engaged learning environment. In terms of the factors informing teachers' usage of an inquiry-based learning as an instructional approach, it found that inquiry-based teaching strategies benefit culturally and linguistically diverse learners, as well as those with special needs. Regardless of learners' backgrounds and challenges, the study revealed a significant positive impact of inquiry-based instruction on their academic achievement. These findings align with prior research suggesting a linear relationship between inquiry-based instruction frequency and science academic achievement. However, conflicting evidence arises from recent studies, such as Teig, Scherer, and Nilsen (2018), who identified a curvilinear relationship between inquiry-based instruction and academic achievement.

The current study thus highlighted teachers' awareness of the potential of inquiry-based teaching to enhance learner achievement and reduce achievement gaps. Despite lacking the necessary tools for implementation, teachers recognised the value of incorporating inquiry-based instruction in science classrooms. The study suggests that the full realisation of successful science inquiry-based instruction and practical work in Namibia is contingent on addressing and eliminating existing obstacles faced by Namibian science teachers in facilitating the teaching process. Despite teachers expressing a value for inquiry-based instruction, limitations emerged when applying it in science teaching, rooted in teachers' intrinsic and extrinsic behaviours. Extrinsic behaviours, influenced by external factors, included motivation issues, insufficient subject-matter knowledge, inadequate pedagogical content knowledge, and poor teaching skills. Intrinsic behaviours were linked to personal attitudes, beliefs, and ideas about inquiry. Challenges identified by teachers aligned with literature, encompassing factors like limited time, inadequate professional development, classroom management issues, and heavy workloads (Shivolo, 2018).

Numerous researchers have acknowledged the positive impact of incorporating inquiry-based learning in science education, particularly in subjects such as Biology, Physics, and Chemistry (Gholam, 2019). Aligning teaching methods with learners' skills is deemed crucial for success in future science-related fields (Marks, 2013) and has been found to enhance speaking skills (Irawan, Syahrial & Sofyan, 2018). Meirbekov and Salikhanova (2021) have identified several benefits of inquiry-based learning, including strengthening curriculum content, facilitating intelligent preparation for further learning, fostering deeper understanding of course materials, enhancing tutorial utility, fostering learner initiative and self-directed learning, encouraging inquiry-based practices in science classes, and promoting differentiated learning approaches. This study's findings align with existing literature, suggesting that Namibian science teachers are on par with global trends in recognising the advantages of inquiry-based learning in science classrooms.

Conclusion

Teachers in Namibia emphasised the significance of inquiry-based instruction as a pivotal element within the learner-centred approach, a contemporary teaching method reflected in science education curriculum documents. Particularly, the Physical Science Syllabus for Grades 8 & 9 (2015), Chemistry Syllabus for Advanced Subsidiary Level Grade 12 (2020), Physics Syllabus for Advanced Subsidiary Level Grade 12 (2020), Chemistry Syllabus for Ordinary Level Grade 10–11 (2018), Physics Syllabus for Ordinary Level Grade 10–11 (2018), and the Ministry of Education's (MoE) guidelines from 2006 all incorporate this approach. While the questionnaire survey results indicated teachers' recognition of inquiry-based instruction's importance in science classrooms, a more intricate viewpoint emerges from classroom observations and interviews. Despite teachers' conceptual understanding of inquiry-based instruction, various impediments hinder its effective implementation, including resource unavailability, teachers' insufficient skills, behavioural challenges among both teachers and learners, and the constraints imposed by large class sizes. Consequently, despite teachers' comprehension of the inquiry-based approach, practical challenges impede its seamless integration into science education.

Recommendations

The investigation indicates a disparity in resource allocation for science practical work in Namibian schools, suggesting the imperative provision of laboratories, science kits, and apparatus across all schools. This recommendation aims to empower teachers to cultivate investigative and experimental skills in learners from the

primary phase onwards. To address this persistent issue, it is proposed that annual budget allocations should include provisions for school laboratories and science kits, involving regional personnel, circuits, and teachers.

Additionally, the assessment of objective C is advised to commence in Grade 8 through 9, extending to Grade 11, challenging curriculum planners and reviewers to integrate investigative activities into the junior secondary phase. Teacher engagement in seminars and workshops on syllabus interpretation and suggested practical activities is advocated, supported by the assignment of experienced science experts (experienced teachers) for nationwide awareness campaigns and collaboration with teacher training institutions. These initiatives should emphasise practical work facilitation using affordable, locally available materials, targeting in-service teachers.

Lastly, the study recommends revisiting the debate on timetable allocation for science practical work, echoing the sentiments of science scholars in Namibia (Asheela, Ngcoza & Sewry, 2020; Shivolo, 2018; Asheela, 2017). To mitigate teachers' reluctance due to limited time, curriculum science reviewers are urged to advocate for increased time allocation for scientific and inquiry-based activities through updates to the National Curriculum and Assessment Policy for Basic Education (NCBE).

Notes

This study originates from the doctoral thesis in science education of the first author.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in JESEH journal belongs to the authors.

References

- Abrahams, I., & Reiss, M. J. (2012). Practical work: Its effectiveness in primary and secondary schools in England. *Journal of Research in Science Teaching*, 49(8), 1035–1055. <https://doi.org/10.1002/tea.21036>
- Asheela, E. N. (2017). *An intervention on how using easily accessible resources to carry out hands-on practical activities in science influences science teachers' conceptual development and dispositions*. Unpublished Master's thesis, Rhodes University, Grahamstown.
- Asheela, E., Ngcoza, K. M., & Sewry, J. (2020). The use of easily accessible resources during hands-on practical activities in rural under-resourced Namibian schools. *In School science practical work in Africa* (pp. 14-31). Routledge.
- Bandura, A. (2014). Social cognitive theory of moral thought and action. *In Handbook of moral behavior and development* (pp. 69-128). Psychology press.
- Baptista, G. C. S., & Molina-Andrade, A. (2021). Science teachers' conceptions about the importance of teaching and how to teach Western science to students from traditional communities. *Human Arenas*, 1-28.
- Baroudi, S., & Rodjan Helder, M. (2021). Behind the scenes: teachers' perspectives on factors affecting the implementation of inquiry-based science instruction. *Research in Science and Technological Education*, 39(1), 68–89. <https://doi.org/10.1080/02635143.2019.1651259>
- Bradley, J. (2021). Achieving the aims of practical work with microchemistry. *In Research in chemistry education* (pp. 23-30). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-59882-2_2
- Bueno, O. (2013). Perception and conception: Shaping human minds. *Biosemiotics*, 6(3), 323–336.
- Capps, D. K., Crawford, B. A., & Constat, M. A. (2012). A review of empirical literature on inquiry professional development: Alignment with best practices and a critique of the findings. *Journal of science teacher education*, 23(3), 291-318. <https://doi.org/10.1007/s10972-012-9275-2>
- Caravias, V. (2018). Teachers' conceptions and approaches to blended learning: A literature review. *Online Course Management: Concepts, Methodologies, Tools, and Applications*, 912-934.
- Chan, K. K. H., & Hume, A. (2019). Towards a consensus model: Literature review of how science teachers' pedagogical content knowledge is investigated in empirical studies. *Repositioning Pedagogical Content Knowledge In Teachers' Knowledge for Teaching Science*, 3-76.

- Clarke, V., Braun, V., & Hayfield, N. (2015). Thematic analysis. In: Smith, J.A., Ed., *Qualitative psychology: A practical guide to research methods*, SAGE Publications, London, 222-248.
- Cobern, W. W., Schuster, D., Adams, B., Skjold, B. A., Muğaloğlu, E. Z., Bentz, A., & Sparks, K. (2014). Pedagogy of science teaching tests: Formative assessments of science teaching orientations. *International Journal of Science Education*, 36(13), 2265-2288.
- Crawford, B. A. (2014). From inquiry to scientific practices in the science classroom. In *Handbook of research on science education, Volume II* (pp. 529-556). Routledge.
- Dawadi, S. (2020). Thematic analysis approach: A step by step guide for ELT research practitioners. *Journal of NELTA*, 25(1-2), 62-71.
- Demirdöğen, B., & Uzuntiryaki-Kondaçcı, E. (2016). Closing the gap between beliefs and practice: Change of pre-service chemistry teachers' orientations during a PCK-based NOS course. *Chemistry Education Research and Practice*, 17(4), 818-841.
- Dewey, J. (1929). The sphere of application of the excluded middle. *The Journal of Philosophy*, 26(26), 701-705.
- Gess-Newsome, J. (2015). A model of teacher professional knowledge and skill including PCK. I: A. Berry, P. Friedrichsen & J. Loughran (red.). *Re-examining Pedagogical Content Knowledge in Science Education*, (Vol. 395), 28-42.. New York, NY: Routledge
- Hitchcock, J. H., & Onwuegbuzie, A. J. (2020). Developing mixed methods crossover analysis approaches. *Journal of Mixed Methods Research*, 14(1), 63-83.
- Hofstein, A., Kipnis, M., & Abrahams, I. (2013). How to learn in and from the chemistry laboratory. In *Teaching Chemistry—A Study Book* (pp. 153-182). Brill Sense.
- Holt, E. B., & Brown, H. C. (1931). *Animal drive and the learning process, an essay toward radical empiricism* (New York: H. Holt and Company).
- Ireland, J. E., Watters, J. J., Brownlee, J., & Lupton, M. (2012). Elementary teacher's conceptions of inquiry teaching: Messages for teacher development. *Journal of Science Teacher Education*, 23, 159-175. <https://doi.org/10.1007/s10972-011-9251-2>
- Jagodźiński, P., & Wolski, R. (2015). Assessment of application technology of natural user interfaces in the creation of a virtual chemical laboratory. *Journal of Science Education and Technology*, 24, 16-28. <https://doi.org/10.1007/s10956-014-9517-5>
- Jokiranta, K. (2014). *The effectiveness of practical work in science education*. Bachelor's Thesis.
- Keller, M. M., Neumann, K., & Fischer, H. E. (2017). The impact of physics teachers' pedagogical content knowledge and motivation on students' achievement and interest. *Journal of Research in Science Teaching*, 54(5), 586–614. <https://doi.org/10.1002/tea.21378>
- Kidman, G. (2012). Australia at the crossroads: A review of school science practical work. *Eurasia Journal of Mathematics, Science and Technology Education*, 8(1), 35–47. <https://doi.org/10.12973/eurasia.2012.815a>
- 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.
- Linn, M. C., Bell, P., & Davis, E. A. (2004). Specific design principles: Elaborating the scaffolded knowledge integration framework. *Internet Environments for Science Education*, 315-340.
- Magnusson, S., Krajcik, J., & Borke, H. (1999). Nature, sources, and development of pedagogical content knowledge for science teaching. In J. Gess-Newsome and N. G. Lederman (Eds.), *PCK and science education* (95-132). Springer, Dordrecht.
- Maseko, B., & Khoza, H. C. (2021). Exploring the influence of science teaching orientations on teacher professional knowledge domains: a case of five Malawian teachers. *EURASIA Journal of Mathematics, Science and Technology Education*, 17(12), em2041.
- Matos, D. A. S., & Jardimino, J. R. L. (2016). Os conceitos de concepção, percepção, representação e crença no campo educacional: similaridades, diferenças e implicações para a pesquisa. *Educação Formação*, 1(3 set/dez), 20–31. <https://doi.org/10.25053/edufor.v1i3.1893>
- Ministry of Education, Arts and Culture. (2015). *Physical science syllabus grades 8 and 9*. Okahandja: NIED.
- Ministry of Education, Arts and Culture. (2020). *Chemistry syllabus, Advanced subsidiary level*. Okahandja: NIED.
- Ministry of Education, Arts and Culture. (2020). *Physics syllabus, Advanced subsidiary level*. Okahandja: NIED.
- Ministry of Education, Arts and Culture. (2020). *National subject policy guide for physical science grades 8 - 9, physics and chemistry grade 10 - 11*. Okahandja: NIED.
- Ministry of Education, Arts and Culture. (2018). *National curriculum for basic education (NCBE)*. Okahandja: NIED.
- Ministry of Education, Arts and Culture. (2018). *Physics syllabus ordinary level grade 10 – 11*. Okahandja: NIED.

- Ministry of Education, Arts and Culture. (2018). *Chemistry syllabus ordinary level grade 10 – 11*. Okahandja: NIED.
- Mohammed, S. M., & Amponsah, K. D. (2021). Teachers' and educational administrators' conceptions of inquiry: Do they promote or constrain inquiry-based science teaching in junior high schools? *Journal of Curriculum and Teaching*, 10(3), 58–71. <https://doi.org/10.5430/jct.v10n3p58>
- Mokiwa, H. O. (2014). Exploring the teaching of Physical Science through inquiry. *International Journal of Educational sciences*, 7(1), 21-27.
- Mokiwa, H. O., & Nkopodi, N. (2014). Inquiry-based teaching in physical science: Teachers' instructional practices and conceptions. *Mediterranean Journal of Social Sciences*, 5(23), 1074–1082. <https://doi.org/10.5901/mjss.2014.v5n23p1074>
- Motlhabane, A. (2013). The voice of the voiceless: Reflections on science practical work in rural disadvantaged schools. *Mediterranean Journal of Social Sciences*, 4(14), 165–173. <https://doi.org/10.5901/mjss.2013.v4n14p165>
- Muyoyeta, N. K. (2018). *Factors affecting Grade 12 learners' academic performance in the Namibia Senior Secondary Certificate ordinary level Biology in the Khomas educational region, Namibia* (Masters Dissertation, University of Namibia).
- National Research Council. (2012). *A framework for K – 12 science Curriculum practices crosscutting concepts and ideas*. Washington, DC: American Association for Advancement of Science.
- National Research Council. (2013). *Next generation science standard: for states, by states*. Washington DC: The National Academies Press.
- Nilsson, P., & Loughran, J. (2012). Exploring the development of pre-service science elementary teachers' pedagogical content knowledge. *Journal of Science Teacher Education*, 23(7), 699-721. <https://doi.org/10.1007/s10972-011-9239-y>
- Onwuegbuzie, A. J., & Hitchcock, J. H. (2022). Towards a comprehensive meta-framework for full integration in mixed methods research. In *The Routledge handbook for advancing integration in mixed methods research* (pp. 565-606). Routledge.
- Ramnarain, U. (2016). Understanding the influence of intrinsic and extrinsic factors on inquiry-based science education at township schools in South Africa. *Journal of Research in Science Teaching*, 53(4), 598-619.
- Ramnarain, U. (2021). *School science practical work in Africa; Experiences and Challenges; First Edition*.
- Ramnarain, U., & Hlatswayo, M. (2018). Teacher beliefs and attitudes about inquiry-based learning in a rural school district in South Africa. *South African Journal of Education*, 38(1). 10.15700/saje.v38n1a1431
- Saldaña, J. (2015). *The coding manual for qualitative researchers*. London: Sage.
- Sedumedi, T. D. T. (2017). Practical work activities as a method of assessing learning in chemistry teaching. *Eurasia Journal of Mathematics, Science and Technology Education*, 13(6), 1765–1784. <https://doi.org/10.12973/eurasia.2017.00697a>
- Shivolo, T. (2018). *Teachers' Pedagogical orientations in grade 8 teacher-orchestrated chemistry practical demonstrations: A focus on Oshikoto Region, Namibia* (Master's Dissertation). Johannesburg: University of Johannesburg. Available from: <https://hdl.handle.net/10210/402293> (Accessed: 11 November 2023).
- Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, 57, 1–22.
- Sotiriou, S. A., Bybee, R. W., & Bogner, F. X. (2017). PATHWAYS—A case of large-scale implementation of evidence-based practice in scientific inquiry-based science education. *International Journal of Higher Education*, 6(2), 8-19. <https://doi.org/10.5430/ijhe.v6n2p8>
- Sshana, Z., & Abulibdeh, E. S. (2020). Science practical work and its impact on students' science achievement. *Journal of Technology and Science Education*, 10(2), 199–215. <https://doi.org/10.3926/JOTSE.888>
- Sundler, A. J., Lindberg, E., Nilsson, C., & Palmér, L. (2019). Qualitative thematic analysis based on descriptive phenomenology. *Nursing open*, 6(3), 733-739.
- Tashakkori, A., & Teddlie, C. (2021). *Sage handbook of mixed methods in social & behavioral research*. SAGE Publications.
- Taylor, D. L., & Booth, S. (2015). Secondary physical science teachers' conceptions of science teaching in a context of change. *International Journal of Science Education*, 37(8), 1299-1320.
- Teo, T. W., Tan, K. C. D., Yan, Y. K., Teo, Y. C., & Yeo, L. W. (2014). How flip teaching supports undergraduate chemistry laboratory learning. *Chemistry Education Research and Practice*, 15(4), 550-567.
- 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 Driel, J. H., Berry, A., & Meirink, J. (2014). Research on science teacher knowledge. In *Handbook of Research on Science Education, Volume II* (pp. 862-884). Abingdon, UK: Routledge.
- Wei, B., & Li, X. (2017). Exploring science teachers' perceptions of experimentation: implications for restructuring school practical work. *International Journal of Science Education*, 39(13), 1775–1794. <https://doi.org/10.1080/09500693.2017.1351650>
- Wei, B., & Liu, H. (2018). An experienced chemistry teacher's practical knowledge of teaching with practical work: The PCK perspective. *Chemistry Education Research and Practice*, 19(2), 452-462.
- 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(4), 723–738. <https://doi.org/10.1007/s10763-018-9886-y>
- Wellington, J., & Ireson, G. (2017). Language in science teaching and learning. In *Science learning, science teaching* (pp. 199-224). Routledge.
- Yung, B. H. W., Zhu, Y., Wong, S. L., Cheng, M. W., & Lo, F. Y. (2013). Teachers' and students' conceptions of good science teaching. *International Journal of Science Education*, 35(14), 2435-2461

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